A

COMPENDIOUS SYSTEM OF Natural Philoſophy.

With NOTES

Containing the

MATHEMATICAL DEMONSTRATIONS,

AND

Some Occaſional REMARKS.

PART II.

HYDROSTATICS and PNEUMATICS.

To which are annexed ſome DISSERTATIONS relating to theſe Subjects.

By J. ROWNING, M. A.

Rector of ANDERBY in LINCOLNSHIRE, and late Fellow of MAGDALEN COLLEGE in CAMBRIDGE.

The THIRD EDITION.

LONDON:

Printed for SAM. HARDING Bookſeller, on the Pavement in St. *Martin's Lane.*

M.DCC.XXXVII.

A

COMPENDIOUS SYSTEM OF Natural Philoſophy.

PART II.

HYDROSTATICS.

CHAP. I.

Of the Phænomena which ariſe from the mutual Action of the Particles of Fluids upon one another.

I. IN the former Part of this Eſſay, I have laid down, and explained the general *Laws of Nature*, and from thence deduced thoſe Phænomena, which are in a ſtrict and proper Senſe * denominated *Me-*

* In a larger Senſe all the Effects and Operations of natural Bodies upon one another may be called Mechanical; as being all ſubject to the general Laws of Motion. In Hydroſtatics Fluids are governed by the Laws of Mechaniſm, as much as the Mechanical Powers themſelves are; the ſame holds of the

chanical; I proceed now to an Explanation of ſuch, as Philoſophers have comprehended under the Name of *Hydroſtatics*; the Intention of which is to explain the Nature of *Fluids*, and the Manner, wherein they act upon one another, and upon Solids.

II. The Nature of a *Fluid* *, as diſtinguiſhed from that of a *Solid*, or hard Body, conſiſts in this, *viz.* that its Particles are ſo looſely connected together, that they readily move out of their Places, when preſſed with the leaſt Force one Way more then another †.

Rays of Light, as will be ſeen when we come to Optics; and in the larger Bodies of the Planetary Syſtem, Mechaniſm equally prevails, as has been demonſtrated by Sir *Iſaac Newton*; which we ſhall endeavour to make out (when we treat of Aſtronomy) ſo far as the Nature of our Deſign will permit.

* Some Philoſophers make the following Diſtinction in Fluids; thoſe which flow or ſpread themſelves till their Surfaces become level or horizontal, they call *Liquid*; in Contradiſtinction to Flame, Smoak, Vapour, *&c.* which are alſo Fluids, but do not acquire ſuch a Surface. Thoſe, which are capable of exciting in us the Idea of Moiſtneſs, as Water, *&c.* they call *Humid*, diſtinguiſhing them thereby from Air, Quickſilver, and melted Metals. But thoſe Diſtinctions are quite unneceſſary in a Philoſophical Senſe: the Surfaces of all Fluids being level, when not prevented by the Bodies about them; and Humidity is only a *relative* Quality; for tho' Quickſilver will not moiſten, or ſtick to a Man's Fingers, it will to Silver or Gold.

† The common Definition, *Fluidum eſt cujus partes impreſſioni cuicunque cedunt, & cedendo facillimè moventur inter ſe*, though it expreſſes very well the Nature of a *compreſſible* Fluid, as Air, yet does not correſpond to that of Water, whoſe Parts have been found to yield to no Force, with which they have been compreſſed, unleſs it was greater on one Side than on the other. The Definition therefore ſeems imperfect, as not expreſſing that *Inequa-*

From whence Philoſophers conclude, that they are exceedingly minute, ſmooth, and round *; it being otherwiſe impoſſible they

Inequality of Preſſure, which is requiſite to move the Parts of ſome Fluids one among another.

* It is commonly obſerved that the Roundneſs of the Particles conduces very much to Fluidity, not only as it diſpoſes them to move one among another with greater Facility, but becauſe round Bodies touching one another in few Points only, the Force with which they mutually attract each other, is the weaker. But, upon this Suppoſition, the Particles of a Fluid ought to move with leſs Freedom one among another, by how much the greater the Weight is, with which they are compreſſed, (for it is the ſame Thing in this reſpect, whether they preſs againſt each other by Virtue of their own Attraction, or by ſome external Force) but of this we have no Experience. A Diver, upon plunging out of his Bell at the Bottom of the Sea, never finds the Water leſs fluid, notwithſtanding the great Preſſure from above. Mr. *Boyle* having cauſed a Tadpole to be put into a Veſſel of Water, and to be preſſed with a very great Force, tells us, that in Appearance it found no Inconvenience from thence, but ſwam about with the ſame Freedom and Briskneſs as ever.

Quære, Whether the Particles of which Fluids conſiſt, are in Contact with each other, or not? Perhaps, they are prevented from approaching, nearer than to a certain Diſtance, by a repelling Power, diffuſed around each ſingle Particle. The Obſervation, that Water is not render'd leſs fluid by Preſſure, ſeems to favour this Opinion; and the Property, which the Air has of expanding or contracting itſelf, according to the Weight which it ſuſtains (as ſhall be ſhewn Chap. 3.) proves beyond Contradiction, that its Particles are endued with ſuch a Power. But then if the Particles of all Fluids have this Power, it will follow that they ought to be in ſome Meaſure capable of being reduced into leſs Space by Preſſure, as Air is; which they have not as yet appeared to be. Further, ſince it has been proved (Part I. Chap. 3) that if the Parts of Fluids are placed juſt beyond their natural Diſtances from each other, they will approach and run together; and if placed farther aſunder ſtill, will repel each other; it follows, upon the foregoing Suppoſi-

ſhould move with ſuch Freedom one among another, upon the leaſt Inequality of Preſſure.

tion that each Particle of a Fluid muſt be ſurrounded with three Spheres of Attraction and Repulſion one within another: the innermoſt of which is a Sphere of Repulſion, which keeps them from approaching into Contact; the next, a Sphere of Attraction diffuſed around this of Repulſion, and beginning where this ends, by which the Particles are diſpoſed to run together into Drops; the outermoſt of all, a Sphere of Repulſion, whereby they repel each other, when removed out of that Attraction.

Now, if this *Hypotheſis* ſhould be found to be true; and we might agreeably to the above-mentioned Conſequence of it, ſuppoſe, that the Particles of all Bodies attract and repel each other *alternately* at different Diſtances, perhaps we might be able to ſolve a great many Phænomena relating to ſmall Bodies, which now lie beyond the reach of our Philoſophy. However, upon the Suppoſition of the three Spheres of Attraction and Repulſion juſt mentioned, nothing is more eaſy, than to ſee how Solids may be converted into Fluids, and Fluids into Solids (as is done in Liquefaction and Freezing); for allowing, that the firſt or innermoſt Sphere of Repulſion is capable, like that of the Particles of Air, of being augmented by Heat, and diminiſhed or totally ſuſpended by Cold; it follows, that Bodies muſt be more or leſs fluid, in Proportion to the Degree in which they are affected by Heat or Cold: for when the Action of the firſt Sphere of Repulſion is diminiſhed or deſtroyed by Cold, the Particles of the Fluid muſt neceſſarily be brought into cloſer Contact with each other by the Force of the circumambient Attraction, and by that means conſtitute an harder Body than before. But, we muſt not dwell too much upon an Hypotheſis which wants Proof; I ſhall only add, that altho' ſome Fluids, as Water, have not been *as yet* contracted in their Dimenſions, or made to take up leſs Space than they naturally do, by any Force with which they have been compreſſed by *Art*; yet there are none but are *naturally* contracted by Cold, from whence it ſeems reaſonable to infer, that their Particles are at leaſt *capable* of being brought into cloſer Contact, which is ſome Confirmation of this Doctrine.

It is an obvious Objection to this, that Water by freezing is augmented in its Bulk; but this may be owing to thoſe Bubbles or Vacuities, obſervable in the Water after it is frozen, which

III. Thoſe Particles, conſidered ſeparately, are endued with all the common Properties of Matter, and ſubject to the ſame Laws of Motion and Gravitation with larger Bodies. To enquire therefore into the Nature of Fluids, is to conſider, what Appearances a Collection of very ſmall round Bodies, ſubject to thoſe Laws, will exhibit under different Circumſtances. In order to which, it is uſual with Hydroſtatical Writers to conſider a Fluid, as divided into ſeveral perpendicular Columns contiguous to each other. Sometimes it is convenient to conceive it divided into thin Plates or *Strata* lying upon one another. In ſome Caſes, the ſame Fluid is conſidered, as diſtinguiſhed both theſe Ways, *viz.* into perpendicular Columns, and alſo into thin Strata or Plates. Figure 1. repreſents a Veſſel filled with a Fluid to the Height EF, and divided into the Columns GH, IK, LM, *&c.* and alſo into the Strata RS, TV, XY, *&c.*

IV. From this Obſervation, concerning the Properties of the Particles conſidered ſeparately, immediately reſults the following Propoſition, *viz.* that in a Veſſel, whoſe Form is ſuch as is repreſented by ABCD, (*Fig* 1.) the Quantity of Preſſure, which each Stratum ſu-

which were not in it before; and not to any general and uniform Removal of the Particles of the Fluid from each other, which the Objection, if it is of any Force againſt what has been advanced, muſt ſuppoſe.

ſtains,

ſtains from the Weight of the incumbent Fluid, is in Proportion to the Number of thoſe Strata, which reſt upon it, that is, as the Height of the Surface of the Fluid above it; for if we ſuppoſe the Strata of equal Thickneſs, the Quantity ſuſtained is proportionable to the Number of Strata of which it conſiſts.

V. When the Surface of a Fluid is horizontal or level, each Particle thereof is diſpoſed to continue in its Place, being ſuſtained therein by the contiguous ones.

Let the Fluid be ſuppoſed to be divided into Strata, each of the Thickneſs of a Particle of the Fluid; and if the Truth of this Propoſition be denied, let the Particle *mn* be one of thoſe which is not ſuſtained in its Place by the contiguous ones, but is moving from thence towards ſome other Part of the Veſſel, *v. g.* towards D. Now, ſince all the other Particles of that Stratum are at an equal Depth below the Surface of the Fluid with this, they alſo ſuſtain an equal Degree of Preſſure (by the laſt Propoſition,) conſequently for the ſame Reaſon that one of them is moving towards D, the reſt may all be ſaid to be moving in the ſame Direction: But this cannot be true of the whole Stratum, while the Veſſel is entire, and therefore of none of its Parts. Now, the like Reaſoning will hold againſt the Motion of the Particle *mn* towards any other Part of the Veſſel; from whence it follows,

ſollows, that each Particle of the Fluid, is ſuſtained in its Place by the contiguous ones, and therefore diſpoſed to continue at Reſt *.

VI From hence is derived a fundamental Propoſition in Hydroſtatics, *viz.* That when the Surface of a Fluid is level, whatever Preſſure any ſingle Particle or ſmall Portion of it ſuſtains from the contiguous ones on one Part, it ſuſtains the ſame on all the reſt; that is, it is preſſed by them with an equal Degree of Force on all Sides †.

For, by the Definition of the Fluid (§. 2.) each Particle is diſpoſed to give Way, and move out of of its Place, when the Preſſure is not equal on all Sides; and (§. 5.) each Particle is preſſed by the contiguous ones in ſuch a Manner, that it is ſuſtained in its Place thereby; it is therefore preſſed with an equal Degree of Force on all Sides.

* This ſhews us the Abſurdity of ſome Philoſophers, who make the Nature of a Fluid, as contradiſtinguiſhed from that of a Solid, to conſiſt ſolely in the inteſtine Motion of its Particles.

† This Propoſition with its Corollary is not ſtrictly ſpeaking true, unleſs the Particle or Portion of Fluid we ſpeak of is ſuppoſed void of Gravity, for it preſſes downwards with a Force equal to the Weight of thoſe Particles which reſt upon it, added to its own; whereas the Force with which it preſſes upwards is only equal to the Weight it ſuſtains, *viz.* that of the incumbent Fluid. But the Particles of Fluids are ſo exceedingly minute, and the Gravity of each ſo very ſmall, that the Error ariſing from hence can never be ſenſible.

Corol.

Corol. From hence it follows, that each Particle or ſmall Portion of a Fluid preſſes with the ſame Degree of Force in all Directions on thoſe which are contiguous to it. For, by the third Law of Nature, every Particle preſſes upon the contiguous ones with the ſame Degree of Force, with which it is preſſed upon by them.

VII. The Surface of a Fluid becomes level by its own Gravity, when no external Force prevents it from being ſo.

For, the Particles of Fluids preſs in all Directions with Forces proportionable to the Height of their Surfaces (Cor. §. 6. and §. 4.) if then the Surface be not level, the different Parts of the ſame inferior Stratum will be preſſed not only downwards, but ſideways againſt each other with unequal Forces; the greater Preſſure therefore overcoming the weaker, the Particles which ſuſtain the leaſt Preſſure, will be driven out of their Places and raiſed up, till the Surface becomes level; the Surface being level, each Particle will be equally preſſed in every Direction, (§. 8.) all therefore will remain at Reſt, and the Surface continue in that State *

* This Demonſtration, as alſo the foregoing, is founded upon a Suppoſition, that Bodies tend downwards by their Gravity in Lines parallel to each other, which though *phyſically* true, is not ſtrictly ſo, their Tendency being towards the Center of the Earth, and conſequently in Lines which meet in a Point: and therefore, if we would be accurate, the Fluid contained

VIII. Fluids gravitate in Fluids of the ſame Kind.

This Propoſition is a neceſſary Conſequence of what has been obſerved about the Nature of the Particles of which Fluids conſiſt, *viz.* that they are ſolid, and endued with the ſame Properties with other Bodies. The Reaſon why their Gravity is not ſenſible in the Fluid, is becauſe the lower Parts ſuſtain

tained in a Veſſel ſhould be conſidered, as divided into Columns and Strata, as repreſented Figure the ſecond, where ABD is the Earth, C its Center, EFGH a Fluid contained in a Veſſel, and divided into Columns, which if continued down to the Center of the Earth, would there terminate in a Point C; and into the concentric Strata, *ab*, *cd*, &c. having the Center of the Earth for the Center of their Convexity. And then we ſhould find that the Particles of the Fluid will not be in Æquilibrio with each other, till all the Parts of its Surface are at equal Diſtances from the Center of the Earth, forming thereby the Surface EF, concentric to that of the Earth. For, ſuppoſing the Fluid EFGH continued down to C, ſo as to fill the Space ECF; it is evident the Columns, into which the Fluid is divided, cannot be of equal Lengths, and therefore cannot be of an exact Counterpoiſe to each other, unleſs the Surface EF is a Portion of a Sphere, whoſe Center is C: but the Action of the Parts of the Fluid upon each other at the Surface, is the ſame, whether the lower Part GCH be a Fluid, or not. Conſequently the Surfaces of Fluids are not level or plain, but convex, having the Center of the Earth for the Center of their Convexity.

This Convexity, by Reaſon of the great Diſtance of the Earth's Center, approaches ſo near to a Plane, that in ſmall Portions of it, the Difference is not ſenſible, and therefore may be neglected: but at Sea 'tis evident to Senſe; for when the Mariners put to Sea, the Shore firſt diſappears, then the lower Buildings, afterwards the Towers, Mountains, &c.; in like Manner, when they approach a diſtant Ship, the Top of its Maſt and Sails appear firſt, while the Ship itſelf is intercepted from their View, by the Convexity of the Water between them.

the upper, and hinder them from deſcending. But, it does not follow from thence, that the Gravity of the uppermoſt is entirely taken away, as ſome * Philoſophers have imagined; for, as much as the lower Parts preſs againſt the upper in ſuſtaining them; juſt ſo much do the upper by their Reaction preſs upon the lower. Thus, the Weight of the whole Fluid is communicated to the Veſſel, which therefore weighs according to the Quantity it contains, notwithſtanding the Preſſure of each Portion of the Fluid, taken ſeparately, ſeems not to effect it.

IX. The Preſſure of a Fluid is in Proportion to its perpendicular Height, and the Quantity of Surface againſt which it preſſes,

This Propoſition admits of four Caſes.

1. When the Fluid is contained in a Veſſel of the ſame Dimenſion from Top to Bottom, and held in an erect Poſition, as that repreſented Fig. 1. it is evident, the Preſſure of the Fluid upon the Bottom will be in Proportion to its Magnitude, and the perpendicular Height of the Surface of the Fluid above it. For, conceiving it divided into Columns, the Preſſure upon the Bottom, by the fourth Propoſition, will be as the Length or Height of the Column: and it will alſo be as the

* This was the Notion of the *Carteſians*, who held, that when a Fluid is mixed with another of the ſame Kind, it loſes its own Weight thereby.

Num-

Number of them, becauſe the Quantity of Fluid, which preſſes upon the Bottom, is in that Proportion, that is, as the Magnitude of the Bottom preſſed upon. But when the Veſſel is inclined or irregular, the Truth of this Propoſition is ſo far from being evident, that it has been commonly looked upon as a Paradox.

2. Let the Veſſel ABCD (*Fig.* 3.) be filled with a Fluid to the Height EF, and held in an inclined Poſition, as there repreſented; I ſay, the Preſſure of the Fluid is proportionable to the Magnitude of the Baſe CD, and FG or HD the perpendicular Height of the Surface of the Fluid above it.

For ſuppoſing the Fluid divided into the Strata EI, KM, LO, *&c.* ſo far, as the firſt Stratum EI is prevented from preſſing upon KI the Surface of the next inferior Stratum, by being in ſome Meaſure ſupported by the Side of the Veſſel FI, ſo far is its Preſſure augmented by the Reaction of the oppoſite Side EK upon it, which is exactly equal to the Action of the former, becauſe the Fluid preſſing every Way alike, at the ſame Depths below the Surface, exerts an equal Force againſt both theſe Sides. The Surface therefore of the ſecond Stratum is preſſed with the ſame Degree of Force with which it would be, if the Quantity of Fluid contained in the former Stratum was included within the Space

HKQI, which is exactly equal to it, as having the ſame Baſe KI and the ſame perpendicular Height QI *. Now, this being true of each Stratum, their Preſſure upon CD the Baſe of the Veſſel is the ſame, as if they were all placed perpendicularly over it, and filled the Space RHCD; which they would do, ſince the Sum of their perpendicular Heights QI, KS, LT and NV are equal to HD the perpendicular Height of this Space, and each of their Baſes KI, LM, *&c.* is equal to CD its Baſe †. But, by the foregoing Caſe, if the Space RHCD was filled with a Fluid, the Preſſure of it would be proportionable to the Dimenſions of the Baſe CD, and the perpendicular Height DH, therefore it is the ſame in the inclined Tube ABCD ‖.

3. Let the Veſſel ABC be irregular, as repreſented *Figure* the fourth, and filled with

* 31. *El.* 11. † 31. *El.* 11.

‖ Perhaps it may be thought more Geometrical, to demonſtrate this Propoſition with the Generality of Authors from the Property of the inclined Plane. They conſider AD the lower Side of the Tube, as an inclined Plane, on which the Fluid contained within it reſts, and argue that it loſes thereby a Part of its Weight in Proportion to the Length of the Plane, and therefore occaſions no greater Preſſure upon the Baſe, than if the Veſſel was held erect, and filled only to the ſame perpendicular Height, as when inclined. But this Demonſtration proves too much, for by this Way of Reaſoning, one might ſhew, that the Preſſure of the Fluid EFCD upon the Baſe CD is leſs than the Preſſure of RHCD a Column of the ſame Fluid having the ſame Baſe and equal perpendicular Height with it. For both the inclined, and the perpendicular Column contain the

a Fluid to the Height D, I ſay, the Preſſure of the Fluid upon the Baſe C, is proportionable to the Magnitude of the Baſe, and CD the perpendicular Height of the Surface of the Fluid above it.

In order that the Proof of this Propoſition may be the better underſtood, we muſt premiſe the following *Lemma.* viz,

That wnen a Fluid paſſes through a Pipe, as AB, (*Fig.* 5.) which in ſome Parts is larger than in others, the Moment, or Force with which it moves, is every where the ſame. For while the Fluid is paſſing through the Tube, its Velocity in every Part will be reciprocally as the Quantity of Matter; for Inſtance, it will be as much greater at C, than it is at D, as the Quantity paſſing through C at any Inſtant of Time is leſs than at D, and ſo of the reſt; becauſe a leſs Quantity would be conveyed through the ſmaller Parts of the Tube in the ſame Time, unleſs it ſhould move faſter there in Proportion to the ſmallneſs of them. Now the Momentum of Bodies is partly owing to the Quantity of Matter, and partly to the Velocity; (as explained Part I. Chap. 9. §. 1.) conſequently what the Fluid, which is actual-

the ſame Quantity of Fluid, upon Account of the Equality of their Baſes, and perpendicular Heights; but that reſts upon an inclined Plane which this does not, and therefore preſſes leſs upon the Baſe. But this is contrary both to Demonſtration and Experience, the Argument therefore proves too much.

ly

ly paſſing through the narrower Parts of the Tube, wants in Quantity, is compenſated by its Velocity in thoſe Parts, and what it wants in Point of Velocity in the other Parts is made up by the Quantity paſſing through them; ſo that the Moment is the ſame in every Part of the Tube, whether larger or narrower *. The ſame is true, whatever be the Poſition the Tube is held in.

Let us now conceive the Fluid in the Veſſel ABC (*Fig.* 4.) to be diſtinguiſhed into the Strata EF, GH, IK, *&c.* Let us alſo imagine the Bottom of the Veſſel C to be moveable, that is, capable of ſliding up and down the narrow Part of the Veſſel, *v. g.* from C to GH, (without letting any of the Fluid run out). Let it further be ſuppoſed that this moveable Bottom is drawn up or let down with a given Velocity, while the Veſſel itſelf is fixed and imoveable; it is evident the lowermoſt Stratum, which is contiguous to the Bottom, will be raiſed or let down with the ſame Velocity, and will thereby have a Moment proportionable to that Velocity and the Quantity of Matter it contains: But by the Lemma, all the reſt of the

* Thus, we may obſerve in a River or Canal, that by how much the Breadth or Depth is leſs in any Part, ſo much the more rapid is the Stream in that Part; and on the contrary, where it is wider and deeper, the Motion of the Water is more gentle and languid So that the Moment, with which it flows, is the ſame in every Part.

Strata

Part II. Plate I. *Pag.* 16

Fig. 1. *P.* 7.

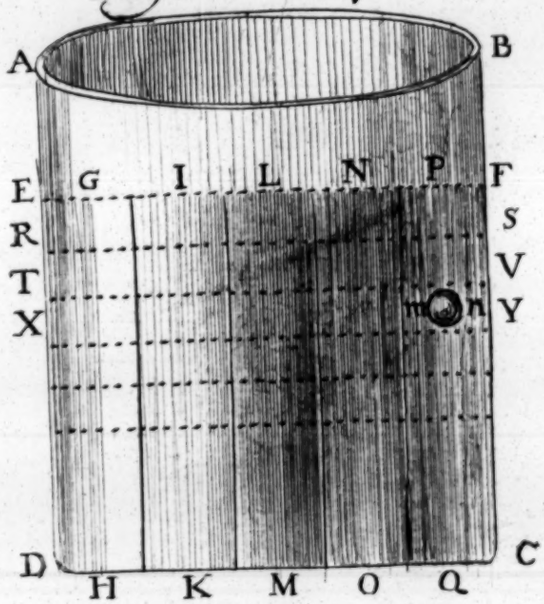


Fig. 2. *P.* 11.

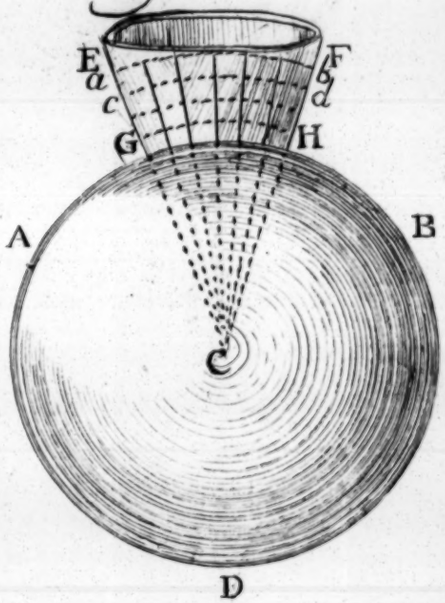


Fig. 3. *P.* 13.

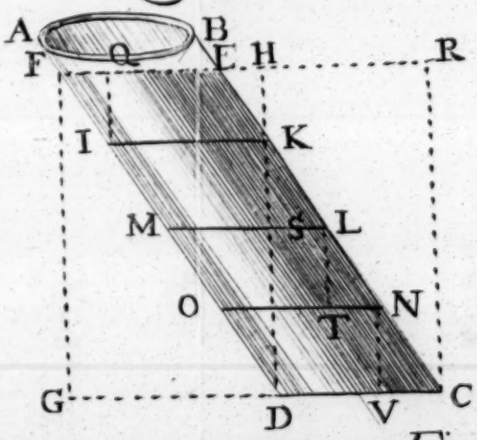


Fig. 4. *P.* 14.

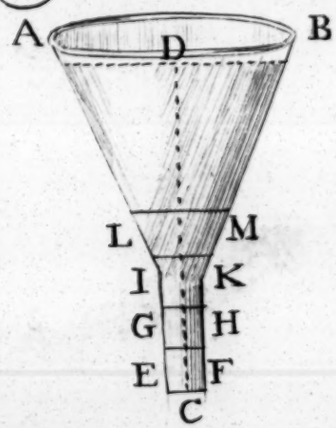


Fig. 5. *P.* 15.

Strata will have the ſame Moment, conſequently the Moment of all taken together, (that is, of the whole Fluid,) is the ſame, as if the Veſſel had been no larger in any one Part, than it is at the Bottom, (for then the Moment of each Stratum would alſo have been as great as that of the lowermoſt); the Preſſure therefore, or Action of the Fluid, with which it endeavours to force the Bottom out of its Place, is as the Number of Strata, that is, the perpendicular Height of the Fluid, and the Magnitude of the lowermoſt Stratum, that is, the Bottom.

Again, ſuppoſe the Veſſel ABC (*Fig.* 6.) fill'd with a Fluid to D; I ſay the Preſſure upon the Bottom BC, is proportionable to the Dimenſions of the Bottom, and to DE the perpendicular Height of the Fluid.

For, if we ſuppoſe the Bottom moveable, as before, and raiſed up or let down with a given Velocity, the Moment of every Stratum will be the ſame with that of the lowermoſt, by the Lemma; therefore the Moment of all taken together, is the ſame, as if the Veſſel had been no leſs in any one Part, than it is at the Bottom; conſequently the Preſſure is proportionable to the perpendicular Height, and the Magnitude of the Bottom. This Caſe is the Converſe of the former *.

* Upon this is founded the Practice of conveying Water through Pipes from Place to Place, &c. For from hence it follows,

From hence it follows, that, if a Veſſel is made of ſuch a Form, as is repreſented (*Fig.* 7.) by ABCDEFG, and filled with a Fluid to the Height C, the Weight which the Bottom ſuſtains, is as great as it would be, had the Veſſel been IKFG (which is every where of the ſame Dimenſions, that the other is of at the Bottom) and filled to the Top IK. Becauſe the Preſſure, by the Propoſition, is proportionable to the Bottom and perpendi-

follows, that if one End of a Pipe is laid in a Reſervoir of Water, the Fluid will run into the Pipe, till it riſes to a Level at the other End with its Surface in the Reſervoir. Thus let ABC (*Fig.* 8.) repreſent a Reſervoir or Baſon of Water, DGE a Pipe laid from thence to E. If E the End of the Pipe is placed above the Line ABF, the Level of the Water in the Reſervoir, the Water will run into the Pipe, till it riſes in the other End to F the Level with AB; at which Time the Water in the Pipe will be in Æquilibrio with that in the Reſervoir, and remain at Reſt. But if the End of the Pipe is below the Surface of the Water in the Reſervoir, it will continue to run out, till they are reduced to a Level. For, let GH be the loweſt Part of the Pipe, then ſince F the perpendicular Height of the Fluid on one Side, is equal to B the perpendicular Height of the Fluid on the other, and GH, which (being the Place where the Fluids preſs one againſt another,) may be conſider'd as a Baſe to both, is common; it follows from this Propoſition, that the Preſſures on each Side are exactly equal; and therefore being in contrary Directions will neceſſarily deſtroy each other, and the Fluid will remain in Æquilibrio. But while the End E is below the Level, this Æquilibrium cannot be obtained; and therefore the Fluid will continue to run out.

For the ſame Reaſon, when two or more Tubes communicate with each other, the Surface of the Fluid they contain will ſtand at the ſame Level in all.

cular

cular Height, which in both Caſes are the ſame *.

X. The Velocity, with which a Fluid ſpouts out at an Hole in the Bottom of a Veſſel, is equal to that, which a Body would acquire by falling freely from the Level of the Surface of the Fluid to the Hole.

Let there be a large cylindrical Tube ABCD (*Fig.* 9.) in the upper Part of which let us imagine a Cylinder of Ice FGHI ex-

* The Reaſon why the Veſſel ABCDEFG, with the Fluid contained in it, does not weigh ſo much, as the Veſſel IKFG, when full to the ſame Height, notwithſtanding the Preſſure upon the Bottom is the ſame in both, is, becauſe ABDE the upper Part, or Cover of the former Veſſel, is preſſed upwards by the Fluid below it, with a Force equal to the Endeavour the Fluid in the ſmall Tube BCD has to deſcend. Which Endeavour is the ſame that it would be, if the Tube BCD comprehended alſo the two Spaces ICBA and CKED, its Moment being the ſame in both Caſes by the Demonſtration; the Cover therefore is preſſed upwards with a Force equal to the Weight of as much Fluid as would fill the two Spaces ICBA and CKED; conſequently the Veſſel, whoſe Form is ABCD EFG, is ſo much lighter than the other, that is, as much as the Fluid it contains is leſs.

From hence ariſes this Paradox, that the leaſt Quantity of Fluid may be made to raiſe any Weight how great ſoever it be.

For ſince the Cover ABDE is preſſed upwards with a Force equal to the Weight of as much Fluid, as would fill the two Spaces ICBA and CKED, and thoſe Spaces may be enlarged at Pleaſure in Height, by lengthening the Tube BCD (which at the ſame Time muſt be made proportionably ſmaller, otherwiſe the ſame Quantity of Fluid will not fill it;) it follows, that the ſame Quantity of Fluid may be made to preſs the Cover upwards with a given Force; if that Cover then is made moveable, any Weight that is laid upon it may be ſupported thereby.

actly fitting it; let it further be ſuppoſed, that HI, the lower Surface of the Ice, is continually melting, ſo as to afford a Stream of Water running down the Middle of the Tube. Now the Form of this Stream of Water will neceſſarily be ſuch, as is repreſented in the Figure by HLI; for the Water falling freely will deſcend faſter and faſter like other Bodies, cauſing thereby the Stream to become narrower and narrower. Now, let it be ſuppoſed, that the Tube has a Bottom as CD, with an Hole in it at K, juſt ſufficient to let the Stream paſs freely; it is evident, there will be no Obſtruction on this Account, but that the Fluid will paſs through the Hole with ſuch Velocity, as it naturally acquires by falling from HI, the lower Surface of the Ice. And if we ſuppoſe M and N, the empty Parts of the Tube, to be filled with Water, the Water will preſs equally upon the Sides of the Stream in every Direction (§. 6.) and therefore will be no Impediment to its Motion on that Account. Laſtly, let us ſuppoſe the Ice taken away, and the Stream ſupplyed from the Water at the Sides, as is the Caſe when a Fluid runs out through the Bottom of a Veſſel; then will the Velocity, with which the Water flows through the Hole, continue the ſame; for ſo far as the Water coming from the Sides, endeavours to deſcend itſelf, ſo far it obſtructs the Deſcent of the Stream, and no farther; and

and conſequently cauſes no Alteration in the Velocity or Quantity of Fluid running out. The Velocity therefore, with which the Fluid paſſes through the Hole, is equal to that, which a Body would acquire by falling freely from the Level of the Surface of the Fluid to that Place.

If the Hole is made in the Side of the Veſſel at the ſame Diſtance below the Surface, the Velocity will be the ſame, on Account of that equal Tendency Fluids have to move every Way alike *.

XI. The Velocity, with which a Fluid ſpouts out from the Bottom or Side of a Veſ-

* Upon this Principle is founded the Practice of making artificial Fountains. For if to a Veſſel or Reſervoir ABCD, (*Fig.* 10.) filled with a Fluid to the Height EF, be fixed the Pipe CH, with a ſmall Aperture at K, the Fluid will ſpout up from thence to FL, the Level of the Surface of the Fluid in the Veſſel. For, by this Propoſition, it will ſpout from K with ſuch a Velocity, as a Body would acquire by falling from FL the Level of the Surface to the Aperture at K, that is, ſuch as will carry it from the Aperture to the Level; becauſe that Velocity which a Body acquires by falling from a certain Height, is ſufficient to carry it back to the ſame Height from whence it fell.

But in Practice the Height the Fluid riſes to, is leſs than that of the Level of its Surface in the Reſervoir: this is owing to the Reſiſtance it meets with from the Air, its Friction againſt the Sides of the Pipe, *&c.* It is found impoſſible to make it much exceed the Height of an hundred Feet: For, when it ſpouts out of the Aperture with a Velocity neceſſary to carry it higher, the Stream is immediately daſhed to Pieces by the Reſiſtance of the Air; whereby it loſes its Force, and is prevented from riſing to any conſiderable Height.

ſel, is as the ſquare Root of the Height of its Surface above the Hole *.

The Cauſe, why a Fluid ſpouts out through an Hole made in the Bottom or Side of a Veſſel, is the Preſſure or Weight of the Fluid incumbent upon the Hole; from whence it ſhould ſeem, that the Velocity ought to be as the Preſſure; but if ſo, then the Quantity run out would alſo be as the Preſſure (for the faſter the Liquor flows, the greater is the Quantity thrown out in a given Time, and *vice verſâ*) conſequently, upon this Suppoſition we ſhould have two Effects, each depending on the ſame Cauſe, and equal to it, which is abſurd. 'Tis not then the Quantity of Fluid run out, nor the Velocity with which it flows, but its Moment, or both theſe multiplied together, (Part I. Ch. 9. §. 1.) that is the true and adequate Effect of the Preſſure. Now theſe being ever in the ſame Ratio, with each other, 'tis neceſſary, in Order that

* This Propoſition may be otherwiſe demonſtrated from the laſt, in the following Manner. For, ſince the Velocity with which a Fluid ſpouts out through an Hole in the Bottom or Side of a Veſſel, is equal to that which a Body would acquire by falling from the Level of the Surface of the Fluid to the Hole, and the Velocities Bodies acquire by falling are as the ſquare Roots of the Heights they fall from (Part I. Chap 5. §. 5.) it follows, that the Velocity, with which a Fluid ſpouts out from an Hole in the Bottom or Side of a Veſſel, is as the ſquare Root of the Height of the Level of the Surface of the Fluid above the Hole.

the

the Effect may be proportionable to its Cauſe, that each of them be only as the ſquare Root of the Preſſure: For then, being multiplied together, their Product, or the Moment of the ſpouting Fluid, is adequately as the Preſſure which occaſions it; but the Preſſure is as the perpendicular Height (§. 4.) therefore the Velocity, and alſo the Quantity of Fluid ſpouting out, is only as the ſquare Root of the Height of its Surface above the Hole.

To give an Inſtance or two; ſuppoſe two Holes made in the Side of a Veſſel, the one an Inch below the Surface of the Fluid it contains, the other four Inches; the Velocity with which the Liquor flows out of the lower Hole, will not be four Times as great, as that with which it flows through the upper, notwithſtanding the Preſſure is four Times greater: For if it ſhould, the Quantity run out in a given Time would alſo be four Times greater, conſequently the Effect produced would be ſixteen Times greater than it is at the upper Hole, that is, four Times greater than the Cauſe; which is abſurd. Whereas the Velocity and Quantity of Matter will each be only twice as great as they are above, producing thereby a Force or Moment only four Times as great, which is proportionable to the Cauſe. So, if an Hole were made ſixteen Times lower than the firſt, the Velocity and Quantity of Matter will not be each ſixteen Times greater than at the other,

other, but only four Times greater apiece, and ſo the Moment ſixteen Times greater, as the Preſſure is *.

XII. When a Current of Water, or other Fluid, falls perpendicularly upon the Surface

* From hence, we may ſee the Error ſome of the foreign Mathematicians have fallen into with Regard to the Forces of moving Bodies, who contend that they are as the Squares of the Velocities multiplied by the Quantities of Matter. For, from this Propoſition it is, that one of the principal Arguments brought in Favour of this Opinion is derived. They argue thus, *Effects* are ever proportionable to their *Cauſes*, the *Preſſure* of the incumbent Fluid is the *Cauſe* of its ſpouting out, the *Force* with which it ſpouts out, is the *Effect*; but by this Propoſition the *Preſſure* is as the *Square* of the *Velocity* it flows with, therefore the *Force* is likewiſe as the *Square* of the *Velocity*. True, it is ſo; but let us ſee the Conſequence. The Force, with which the Fluid ſpouts out is not only owing to the Velocity, but the Quantity run out in a given Time. They have each their Share in producing the Force, conſequently the Force is in a Ratio compounded of both, or as the Product of one multiplied by the other, or, which comes to the ſame Thing, (ſince as was obſerved before, they are in the ſame Ratio with each other) as the Square of either of them. From hence it is that the Forces of Fluids in Motion are ſaid to be as the Squares of their Velocities; not that they are ſo in Virtue of thoſe Velocities, as ſuch, but in Virtue of them, and the Quantities of Matter taken together, or becauſe the Squares of the Velocities is the ſame Thing with the ſimple Velocities multiplied by the Quantities of Matter. Therefore when it is ſaid, the Forces of Fluids are as the Squares of the Velocities, that Part of the Force which ariſes from the Quantity of Matter is really taken into Conſideration. How ridiculous then muſt it be in thoſe Gentlemen to fetch an Argument from hence to prove, that the Forces of Bodies in Motion are as the Squares of the Velocities and Quantities of Matter too, when they are as the Squares of the Velocities, only becauſe the Quantities of Matter are implied in them?

of

Fig. 6. P. 17.

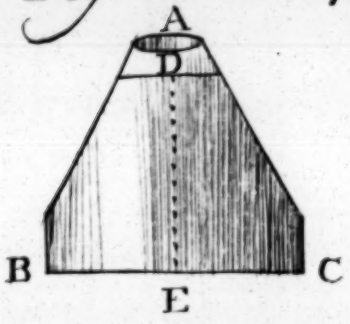


Fig. 7. P. 18.

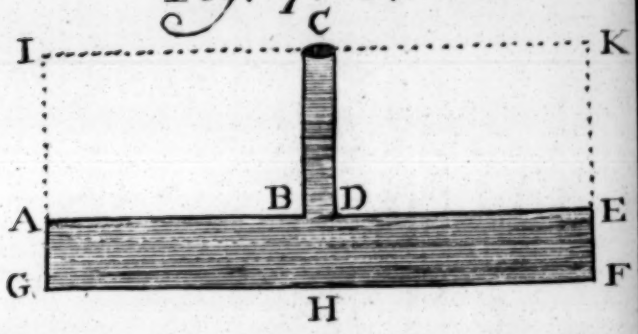


Fig. 8. P. 17.

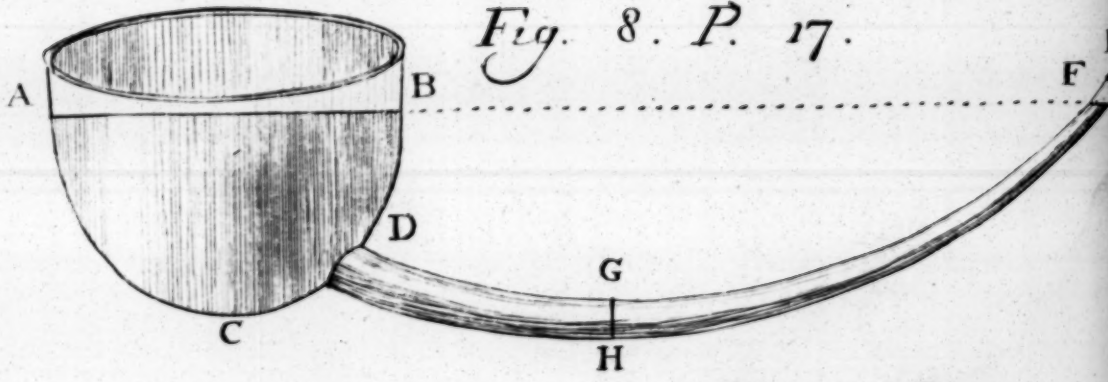


Fig. 9. P. 20.

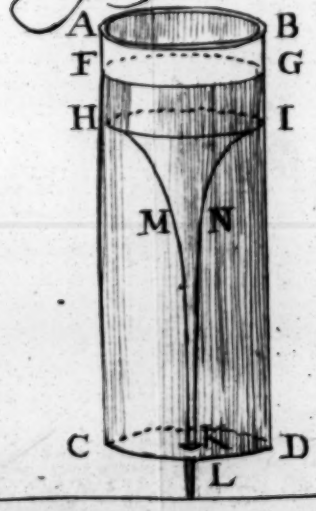
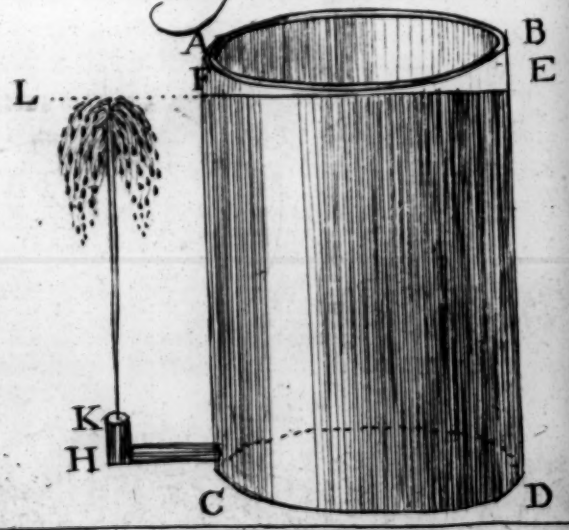


Fig. 10. P. 21.



of a Plane, or flows againſt it, (as the Wind againſt the Sail of a Ship, or the like) the Force, which the Fluid exerts upon it, is equal to the Weight of a Column of the ſame Fluid, whoſe Baſe is equal to the Plane, and its Height ſuch, that a Body falling freely through it would acquire the ſame Degree of Velocity with which the Fluid moves *.

In Order to demonſtrate this Propoſition, let us ſuppoſe the Veſſel ABCD (*Fig.* 11.) filled with a Fluid, and having a large Hole EF in the Bottom, then will the Preſſure of the Fluid cauſe a Stream to flow out, which in the Hole itſelf will have ſuch a Degree of Velocity, as a Body would acquire by falling freely from the Surface of the Fluid in the Veſſel to the Hole (as demonſtrated §. 10.) In the midſt of this Hole, and conſequently in the Stream, let us ſuppoſe a Plane as PQ ſuſpended, but ſomewhat leſs than is ſufficient to fill the Hole, leſt it ſtop the Current of the Water. Now, 'tis certain, this Plane ſupports a Column of the Fluid, equal to that which preſſes upon any other Part of the Bottom of the Veſſel of equal Dimenſions with itſelf (for being thus placed, it may be looked upon as a Part of the Bottom) but every

* From this Propoſition is deduced the Method of computing the Power of a Machine, which is to be moved by Wind or Water, *&c.* See an Inſtance of ſuch a Calculation in the Memoirs of the Royal Academy of Sciences for the Year 1725.

Part

Part bears a Column, whoſe Baſe is equal to its own Dimenſions, and its Height the ſame with that of the Surface of the Fluid in the Veſſel: Conſequently this Plane ſupports ſuch a Column, that is, it is reſiſted by the Stream with a Force equal to the Weight of a Column, whoſe Baſe has the ſame Dimenſions with itſelf, and whoſe Height is equal to that of the Surface of the Fluid in the Veſſel, that is, ſuch an Height as a Body by falling freely from, would acquire a Velocity equal to that with which the Fluid moves.

XIII. The Preſſure of a Fluid againſt a perpendicular Bank or Sluice, *&c.* is equal to the Weight of a Column of the ſame Fluid, whoſe Baſe is equal to ſo much of the Bank as is below its Surface, and which has half the Depth of the Fluid for its Height *.

If the Preſſure upon every Part of the Bank from the Surface to the Bottom, was as great as it is at the Bottom, the Preſſure againſt it would be equal to the Weight of a Column, whoſe Baſe is equal to ſo much of the Bank as is under the Surface of the Fluid, and which has the *whole* Depth of the Fluid for

* From hence we ſee the Reaſon, why the Water of the Sea or great Lakes is as eaſily kept within their Banks (ſetting aſide the Force which ariſes from the Motion of the Waves, *&c.*) as that of the narroweſt Canal, *viz.* becauſe the Preſſure of Fluids is not in Proportion to their Surfaces, but their Depths.

its

its Height; for the Preſſure upon every Part of the Bank at the Bottom is equal to the Weight of a Column, whoſe Baſe correſponds to the Part preſſed upon, and whoſe Height is that of the Depth of the Fluid; conſequently if the Preſſure was the ſame every where from Top to Bottom, it would be equal to the Weight of as many ſuch Columns as would anſwer to all the Parts of the Bank: But the Preſſure every where diminiſhes in Proportion as we approach the Top, where it is Nothing; it is therefore but *half* * what it would be in the other Caſe; from whence the Propoſition is clear.

CHAP. II

Of the Effects Fluids have on Solids immerſed therein.

I. THE *Specific* Gravity of a Body is that, by which it is ſaid to be heavier, or lighter than another of a different Kind: Thus Lead is ſaid to be ſpecifically heavier than Cork; becauſe ſuppoſing an equal Bulk of each, the one would be heavier than the other.

* Becauſe the Sum of a Number of Terms in Arithmetical Progreſſion beginning from Nothing, is half the Sum of an equal Number of Terms, each of which is equal to the laſt in the Progreſſion.

From hence it follows, that a Body, ſpecifically heavier than another, is alſo more denſe, that is, contains a greater Quantity of Matter under the ſame Bulk, becauſe Bodies weigh in Proportion to the Quantities of Matter they contain (Part I. Chap. 3. §. 7.)

II. If a Solid be immerſed in a Fluid of the ſame ſpecific Gravity with itſelf, it will remain ſuſpended therein, in whatever Part of the Fluid it is put.

Let the Body FGHI (*Fig.* 12.) be immerſed in the Fluid ABCD to the Depth MN, or any other whatever; I ſay, it will continue in the ſame Part of the Fluid, when left to itſelf, without either riſing towards the Surface, or ſinking towards the Bottom.

For, the Body being (by the Suppoſition) of equal Gravity with the Fluid, the Weight of the Column KLHI, which conſiſts partly of Fluid, and partly of the Body, is the ſame as if it had been all Fluid; conſequently HI, that Part of the Surface of the Stratum MN, which lies immediately under the Body, is preſſed with the ſame Degree of Force, that any other Part of the ſame Dimenſions is, and therefore the whole Column KLHI will be ſupported in its Place. Now, the ſame being true of the Column KLHI, whatever be its Length, 'tis evident the Body will be ſuſpended in its Place at any Depth.

III.

III. But, if the Body is ſpecifially heavier than the Fluid, in which it is immerſed, it will ſubſide to the Bottom: For then, in whatever Part of the Fluid it is put, the Column KLHI will always be heavier than an equal Column, that conſiſts all of Fluid; conſequently HI, that Part of the Stratum MN which lies immediately under the Body, will ſuffer a greater Preſſure, than any other Part of the ſame Dimenſions; and therefore will give way, and permit the Body to ſubſide continually, till it reaches the Bottom.

IV. On the contrary, if the Body is ſpecifically lighter than the Fluid, it will riſe to the Top, in what Part of the Fluid ſoever it is put. For then, the Column KLHI will always be lighter than an equal Column which is all Fluid; conſequently HI will be leſs preſſed downwards, than any other Part of the ſame Stratum of equal Dimenſions, and will therefore continually riſe up, carrying the Body with it, till it arrives at the Top.

V. A Body, being laid on the Surface of a Fluid ſpecifically heavier than itſelf, ſinks into it, till the immerſed Part takes up the Place of a Quantity of Fluid, whoſe Weight is equal to that of the whole Body.

Let EFGH (*Fig.* 13.) be a Body, floating on a Liquor ſpecifically heavier than itſelf, it will ſink into it, till the immerſed Part IKGH takes up the Place of ſo much Fluid

as is equal to it in Weight. For, in that Caſe, GH, that Part of the Surface of the Stratum upon which the Body reſts, is preſſed with the ſame Degree of Force, as it would be, was the Space IKGH full of the Fluid; that is, all the Parts of that Stratum are preſſed alike, and therefore the Body, after having ſunk ſo far into the Fluid, is in *Æquilibrio* with it, and will remain at Reſt.

From hence it follows, that a Body is as much ſpecifically lighter, than the Fluid on which it floats, as the immerſed Part is leſs than the Whole. For, by how much the leſs the immerſed Part is, ſo much the leſs Fluid is equal in Weight to the whole Body; that is, the Body is ſo much the lighter in Reſpect of the Fluid. And, if the ſame Body be made to float ſucceſſively in Fluids, whoſe ſpecific Gravities differ among themſelves, (but all exceed that of the Body), the lighter the Fluids are, ſo much greater will be the Part immerſed *.

VI. A Body, ſuſpended in a Fluid ſpecifically lighter than itſelf, loſes a Part of its Weight (or rather communicates it to the

* This Phænomenon is what gave riſe to the Hydrometer, an Inſtrument of great Uſe in aſcertaining the Genuineſs of Liquors; for it rarely happens, that the adulterated and the genuine Liquor (however they may agree in Appearance) are of the ſame ſpecific Gravity.

Fluid)

Fluid) equal to that of a Quantity of Fluid of the ſame Bulk.

Let us, inſtead of ſuppoſing the Body ſuſpended in the Fluid, imagine it to be away, and its Place filled with the Fluid; now 'tis evident, this being of the ſame ſpecific Gravity with the circumjacent Fluid, will be entirely ſupported by it, or, if we ſuppoſe the Body to be of the ſame ſpecific Gravity with the Fluid, it will be wholly ſuſpended by it; we ſee therefore the Preſſure of the circumambient Fluid, whereby it endeavours to buoy up the Body, is equivalent to the Weight of ſo much Fluid, as would fill the Place the Body takes up. But, ſince the Fluid preſſes only on the Surface of the Body, that Preſſure is the ſame, whatever be the ſpecific Gravity of the Body; the Body therefore loſes ſo much of its Weight, as the Fluid would naturally buoy up; that is, ſo much, as is the Weight of a Quantity of Fluid of the ſame Bulk.

This Propoſition affords us a Method of determining the Relation, which the ſpecific Gravities of Bodies, whether Fluid or Solid, bear to each other. For, whereas by weighing a Solid in a Fluid ſpecifically lighter than itſelf, we find the abſolute Weight of a Quantity of the Fluid equal to it in Bulk (*viz.* the Weight the Solid loſes) the Relation, that Weight bears to the Weight of the Solid, is the Relation of their ſpecific Gravities; becauſe

cauſe the Weights of Bodies, whoſe Bulks are equal, are as their ſpecific Gravities: conſequently, if the ſame Solid is weighed ſucceſſively in different Fluids (all lighter than itſelf) we gain the Relation, which the ſpecific Gravity of each bears to that of the Solid, and therefore to one another. Again, if different Solids are weighed in the ſame Fluid, the Relation, which the ſpecific Gravity of that Fluid bears to each Solid is had, and therefore alſo the ſpecific Gravities of the Solids among themſelves *.

* Upon this is founded the Uſe of the Hydroſtatical Balance for determining the ſpecific Gravities both of Solids and Fluids. The Practice is thus. Firſt, let the Solid be weighed in Air, that is, out of the Fluid; afterwards in it (this ought to be done by ſuſpending it at one End of the Balance by a String, that is as nearly of the ſame ſpecific Gravity with the Fluid made Uſe of as poſſible, and letting it ſink into the Fluid till it is wholly immerſed below the Surface; if the Fluid is Water, an Horſe-Hair is moſt convenient to hang the Body at the End of the Balance by) then ſubſtract its Weight in the Fluid from its Weight in Air, the Difference is what it loſes in the Fluid. This done, ſay, by the Rule of Proportion, as the Weight loſt in the Fluid is to its Weight in Air, ſo is Unity, or any Number taken at Pleaſure, to a Fourth, which by its Relation to the former, will expreſs the Relation of ſpecific Gravity of the Solid to that of the Fluid. Thus, the Relation, which the ſpecific Gravity of the ſame Fluid bears to that of various Solids, or of the ſame Solid to that of various Fluids, and conſequently the Relation of the ſpecific Gravities of all among themſelves may be obtained.

CHAP.

CHAP. III.

Of the Air.

I. THAT Part of Natural Philoſophy, which treats of the Properties of the *Air*, and the Effects of its *Preſſure* and *Elaſticity*, is called *Pneumatics*.

II. Air is a thin tranſparent elaſtic Fluid ſurrounding the Earth to a certain Height, and taken all together, is called the *Atmoſphere*.

III. That Air is a Fluid, is evident from the eaſy Paſſage it affords to Bodies moving in it: For this ſhews it to be a Body, whoſe Parts eaſily yield to a Preſſure, that is greater on one Side than on the other, which is the Definition of a Fluid.

IV. Air gravitates towards the Earth, or is heavy like other Bodies.

To prove this, we have Abundance of Arguments both from Senſe and Experiment. Thus, when the Hand is applied to the Orifice of a Veſſel, it readily perceives the Weight of the incumbent Atmoſphere, as ſoon as the Air included in the Veſſel begins to be drawn out. Thus, Glaſs-Veſſels exhauſted of their Air (if not ſtrong enough to ſuſtain the Preſſure of the incumbent Atmoſphere) are cruſhed to Pieces by the Weight of the Air without

out. When the Air is exhauſted out of a Veſſel, the Veſſel weighs leſs than before. With a great many more Experiments generally mentioned by Authors on this Subject *.

V. The exact Weight of the incumbent Air is determined by filling a Tube with Mercury, and immerging the open End in a Veſſel of the ſame Fluid: For then the Mercury will run down the Tube, till its Surface is fallen only to the perpendicular Height of about twenty nine or thirty Inches above the Surface of the Mercury in the Veſſel; if the ſame Experiment is made with Water, the Surface of it will ſtand at about the Height of thirty two Feet above the Surface of that in the Veſſel; the Column of Mercury in one Caſe, and the Column of Water in the other, exactly balancing the Weight of a Column of Air, which reaches to the Top of the Atmoſphere, and preſſes upon the Surface of the Fluid in the Veſſels. This is what is called the Torricellian Experiment, from TORRICELLI the Inventor, and is the ſame with the common Barometer.

From hence it follows (Chap. I. §. 9.) that all Bodies, at the Surface of the Earth, ſuſtain as great a Weight from the Preſſure of the Air, as is that of a Column of Water,

* See *Boyle*'s Tracts, or *Graveſande* Lib. II. P. III.

whoſe

whoſe Height is thirty two Feet, and its Baſe equal to the Surface of the Body preſſed upon *.

VI. That the Suſpenſion of the Mercury in the Barometer depends on the Preſſure of the external Air, is beyond all doubt; for if the Barometer is included in the Air-Pump, the Mercury falls in the Tube, in Proportion as the Air is exhauſted out of the Receiver; and if the Air is let in again gradually, the Mercury reaſcends proportionably, till it reaches its former Height.

VII. That the Atmoſphere is extended to a determinate Height, appears from hence; *viz.* that when the Torricellian Tube is removed to a more elevated Place, the ſuſpended Column of Mercury becomes ſhorter; which is, becauſe a ſhorter Column of Air preſſes upon it; or, that the Tube, in this Situation, is nearer the Top of the Atmoſphere.

* The Preſſure of the Atmoſphere upon every ſquare Inch, near the Surface of the Earth, is about fifteen Pounds, being equal to the Weight of a Column of Mercury, whoſe Height is thirty Inches and its Baſe one ſquare Inch. For, ſuch a Column of Mercury would weigh about fifteen Pounds. The Weight of the Atmoſphere therefore, which preſſes upon a Man's Body, is equal to ſo many Times fifteen Pound, as the Surface of his Body contains ſquare Inches.

The Reaſon, why a Perſon ſuffers no Inconvenience from ſo great a Preſſure, is owing to the Air included within the Pores and Fluids of the Body, which by its Reaction is a Counterpoiſe to the Preſſure of the external Air.

VIII. The Elaſticity of the Air is that Property by which it contracts itſelf into leſs Space, when an additional Preſſure is laid upon its; and recovers its former Dimenſions, when the Preſſure is taken off. This is accounted it diſtinguiſhing Property, all the reſt being common to it with other Fluids.

Of this we have numerous Proofs. Thus, a Bladder full of Air being compreſſed by the Hand, the included Air gives way; but when the Preſſure is taken off, the Air expands itſelf, and readily fills up the Cavity, or Impreſſion made in the Surface of the Bladder. And, if a larger Quantity of Air, than is naturally preſſed into a Veſſel by the Weight of the incumbent Atmoſphere, is forced into it by the *Condenſer* (an Engine for that purpoſe) and if that Air is afterwards let out by opening the Veſſel, the Remainder is found to be of the ſame Weight as at firſt; from whence it follows, that the Air, by means of its Elaſticity or Spring, drives out all that which was forced in by the Condenſer, recovers its former Dimenſions, and fills the Veſſel as before.

IX. From hence, together with what has been obſerved about the Preſſure of the Atmoſphere, it follows, that the Air near the Surface of the Earth, is compreſſed into a much narrower Space by the Weight of the Air above, than that which it would naturally take up, was it free from that Preſſure;

ſure; accordingly it is found by Experiment, that, when the Preſſure of the Atmoſphere is taken off from any Portion of the Air, it immediately expands itſelf into a vaſt Extent. Hence it is, that thin Glaſs Bubbles or Bladders filled with Air, being included in the Receiver of the Air-Pump, are broke in Pieces by the Spring of the Air, which they contain within them, when the Preſſure of the external Air in taken off. Thus a Bladder quite flaccid, containing only a ſmall Quantity of Air in it, ſwells upon the Removal of the external Air, and appears diſtended, as if it contained as great a Quantity as poſſible. The ſame Effect is found in carrying a Bladder ſomewhat flaccid to a more elevated Place, for there the external Preſſure being leſs, the Air included in the Bladder is in ſome Meaſure free from the Preſſure of the Atmoſphere; it therefore dilates itſelf, and diſtends the Bladder as in the former Caſe.

X. It is found by Experiment, that the Quantity of Space into which Air may be contracted by Preſſure, is reciprocally proportionable to the compreſſing Force. From whence it follows, that the Denſity of the Air is proportionable to the Preſſure which it ſuſtains; becauſe the leſs the Space is, into which a given Quantity of it is contracted, the denſer it is. As to the utmoſt Degrees of Expanſion and Contraction, which the Air is capa-

ble of, they are as yet unknown. In ſeveral Experiments made by Mr. Boyle, Air in its natural State, that is, preſſed only with the Weight of the incumbent Atmoſphere, dilated itſelf, when that Preſſure was taken off, into more than thirteen thouſand Times the Space it took up before. And, he was able ſo far to compreſs it, that it ſhould take up more than five hundred and twenty thouſand Times leſs Space than that, into which it would dilate itſelf, when free from its Preſſure *.

XI. From this Property it follows, that the Air in the inferior Parts of the Atmoſphere is more denſe, than that, which is at great Heights in the ſame; or, that the Denſity of the Air decreaſes continually, as we approach the Top of the Atmoſphere. For the Denſity of the Air is proportionable to the Force

* See *Boyle*'s Tracts and Experiments on the Spring and Preſſure of the Air.

Various have been the Opinions of Philoſophers concerning the Cauſe of this prodigious Spring in the Particles of Air; ſome holding it to depend on their Figure, which they ſuppoſe to reſemble in ſome Manner little Bundles of Twigs or the Branches of Trees; ſome think them like Fleeces of Wool, others conceive them as rolled up like Hoops, or the Springs of Watches, and endeavouring to expand themſelves by Virtue of their Texture. But Sir *Iſaac Newton* is of Opinion, that ſuch a Texture is by no Means ſufficient to account for that vaſt Power of Expanſion obſerved above; but that each Particle is endued with a repelling Force which encreaſes as they approach one another, and accordingly keeps them aſunder at Diſtances reciprocally proportionable to the Preſſure they ſuſtain.

See *Hales*'s Statical Eſſays. Vol. I. Chap. 6.

with

with which it is compreſſed, and that Force continually decreaſes, as we approach the Top.

Was the Denſity of the Atmoſphere every where the ſame, that is near the Surface of the Earth, its Height (as is computed from the Quantity of Preſſure it exerts in raiſing the Mercury in the Barometer) would be about five Miles. But whereas its Denſity continually decreaſes, as we approach the Top, and it is uncertain how far the Particles may expand themſelves, where there is little or no Preſſure, the true Height cannot be obtained. It is computed to continue of a ſenſible Denſity to the Height of about forty five, or fifty Miles.

XII. The Elaſticity of the Air produces the ſame Effects with its Preſſure.

For, Action being equal to Reaction, the Force, which the Spring of the Air exerts in endeavouring to expand itſelf, is equal to the Force with which it is compreſſed; juſt as it is in the Spring of a Watch, which exerts no Force, but in Proportion as it is wound up; conſequently a Quantity of Air in ſuch a State of Contraction, as it would be compreſſed into by the Weight of the incumbent Atmoſphere, exerts a Force equal to that Weight. If a Quantity of Air therefore is included in a Veſſel, and is of the ſame Denſity with the circumambient Air, its Preſſure againſt the Sides of the Veſſel is equal to the Weight of the Atmoſphere. Thus, Mercury is ſuſtained

to

to the ſame Height by the elaſtic Force of Air included in a Glaſs Veſſel, no Way communicating with the external Air, as by the Weight of the Atmoſphere itſelf.

XIII. The Elaſticity of the Air is augmented by Heat and diminiſhed by Cold *. For if a Bladder, which is about half filled with Air, is laid before the Fire, it will, when it is ſufficiently heated, be diſtended and burſt. Thus, Glaſs Bubbles being laid upon the Fire immediately burſt with great Violence by the augmented Spring of the included Air.

XIV. The Denſity of the Air thus continually varying, according to the different Degrees of Heat and Cold, to which it is expoſed, makes it difficult to aſcertain its true ſpecific Gravity. RICCIOLUS eſtimates it to be to that

* This Property is found in all Bodies both Solid and Fluid. but in a much leſs Degree, than it is in Air, Thus, if a Flask be filled with Water, only to the lower Part of the Neck, and is then ſet upon the Fire, the Water, when it begins to grow warm, will riſe into the Neck, and continue to aſcend, as the Heat is increaſed. And when a Wire or Bar of Iron is heated, it is augmented both in Length and Diameter.

Upon this Property depends the Phænomena of the Thermometer, which is a Glaſs Bubble with a ſmall hollow Stem ariſing from it. This Bubble and Part of the Stem is uſually filled with Mercury, or Spirit of Wine, which will riſe or fall in the Stem, as they are affected by the Heat or Cold of the external Air. If a ſufficient Degree of Heat is ſuddenly applied to this Inſtrument, the Liquor is obſerved to deſcend a little before it riſes, becauſe the Glaſs diſtending itſelf, the Capacity of the Bubble is augmented, before the included Liquor is affected by the Heat.

of Water, as one to a Thouſand: MERSENNUS, as one to one Thouſand three Hundred: Mr. BOYLE, by more accurate Experiments, found it to be, as one to nine Hundred and Thirty eight; and thinks, that, all Things conſider'd, the Proportion of one to a Thouſand may be taken as a Medium; for there is no fixing any preciſe Proportion, becauſe not only the ſpecific Gravity of Air, but that of Water alſo, is continually varying. However, by ſome Experiments made ſince with more Accuracy before the *Royal Society*, the Proportion has been fixed at about one to eight Hundred and Eighty.

XV. Air is neceſſary for the Preſervation of Animal and Vegetable Life; neither will Fire ſubſiſt without it. The Reaſon of this is as yet unknown to Philoſophers. Mr. HALES by ſeveral curious Experiments in his Statical Eſſays makes it probable, that 'tis owing to its Elaſticity *.

CHAP. IV.

Of the Reſiſtance of Fluids.

THE Reſiſtance a Body meets with in moving through a Fluid, is of three Kinds. The firſt ariſes from the Friction of the Body againſt the Particles of the Fluid;

* See his *Analyſis* of it. Statical Eſſays, Vol. I. Chap. 6.

the

the ſecond from their Coheſion or Tenacity among themſelves; the third, from their Inactivity, or the Tendency they have in common with other Bodies, to keep the Places they poſſeſs.

The firſt, *viz.* that which ariſes from the Friction of the Body againſt the Particles of the Fluid, is very inconſiderable; for whatever the Weight is, which preſſes the Particles of a Fluid together, the Freedom, with which a Body moves through it, is not ſenſibly diminiſhed thereby. As was obſerved Chap. I. §. 2. in the Notes.

The ſecond, or that which ariſes from the Tenacity of the Particles of the Fluid, is as the Time the Body takes up in paſſing thro' it *; for the ſhorter the Time is in which the

* We have a very curious Argument in Confirmation of this, and which at the ſame Time illuſtrates the Manner in which a Body makes its Way through a tenacious Fluid, by Sir *Iſaac Newton* himſelf, in a Poſtſcript to a Letter in the Philoſophical Tranſactions No 371. It is as follows. 'Suppoſe Pieces of 'fine Silk, or the like thin Subſtance, extended in parallel 'Planes, and fixed at ſmall Diſtances from each other. Suppoſe 'then a Globe to ſtrike perpendicularly againſt the Middle of 'the outermoſt of the Silks, and by breaking through them to 'loſe Part of its Motion. If the Pieces of Silk be of equal 'Strength, the ſame Degree of Force will be required to break 'each of them; but the Time, in which each Piece of Silk re-'ſiſts, will be ſo much ſhorter as the Globe is ſwifter; and the 'Loſs of Motion in the Globe conſequent upon its breaking 'through each Silk, and ſurmounting the Reſiſtance thereof, 'will be proportional to the Time in which the Silk oppoſes it-'ſelf to the Globe's Motion; inſomuch that the Globe by the 'Reſiſtance of any one Piece of Silk, will loſe ſo much leſs of 'its Motion as it is ſwifter. But on the other Hand, by how 'much

Force of Coheſion is broke through, the leſs Effect it has in reſiſting the Motion of the Body. This Species of Reſiſtance is alſo very ſmall, except in glutinous and viſcid Fluids, whoſe Parts are not eaſily ſeparated.

The third Species is the principal Reſiſtance, that Fluids give to Bodies, and ariſes from their Inactivity or the Tendency the Particles, of which they conſiſt, have to continue at Reſt. The Quantity of this Reſiſtance depends on the Velocity the Body moves with on a double Account: For in the firſt Place, the Number of Particles put into Motion by the moving Body in any determinate Space of Time, is proportionable to the Velocity wherewith the Body moves; and in the next Place, the Velocity with which each of them is moved, is alſo pro-

'much ſwifter the Globe moves, ſo many more of the Silks it 'will break through in a given Space of Time; whence the 'Number of the Silks, which oppoſe themſelves to the Mo- 'tion of the Globe in a given Time, being reciprocally pro- 'portional to the Effect of each Silk upon the Globe, the Re- 'ſiſtance made to the Globe by theſe Silks, or the Loſs of 'Motion the Globe undergoes by them in a given Time, will 'be always the ſame.

'Now if the Tenacity of the Parts of Fluids obſerves the 'ſame Rule, as the Coheſion of the Parts of theſe Silks; name- 'ly, that a certain Degree of Force is required to ſeparate and 'diſunite the adhering Particles, the Reſiſtance ariſing from the 'Tenacity of Fluids muſt obſerve the ſame Rule, as the Re- 'ſiſtance of the Silks; and therefore in a given Time the Loſs 'of Motion, a Body undergoes in a Fluid by the Tenacity of 'its Parts will in all Degrees of Velocity be the ſame; or in 'fewer Words, that Part of the Reſiſtance of Fluids, which 'ariſes from the Coheſion of their Parts, will be uniform.

portionable to the Velocity of the Body; this Species therefore of Reſiſtance is in a duplicate Proportion, or as the Square of the Velocity, with which the Body moves through the Fluid *.

II. Farther the Reſiſtance a Body moving in a Fluid meets with from thence, may be conſidered with Regard to the Fluid; and then it will be found to be more or leſs, according to the Denſity of the Fluid. For by how much denſer the Fluid is, ſo much the greater Number of Particles are to be put into Motion by the Body, in Order to make its Way through it.

III. The next Thing to be conſidered is the Effects of the Reſiſtance of Fluids upon Bodies moving in them; that is, the Retardation, which they cauſe in the Motion of a Body by their Reſiſtance, or the Quantity of Motion they deſtroy.

* This may be otherwiſe demonſtrated from the twelfth Section of the firſt Chapter; for from thence it follows, that the Reſiſtance a Fluid gives to a Solid againſt which it moves, is proportionable to the Height a Body muſt fall from, to acquire ſuch a Degree of Velocity as the Fluid moves with: But the Heights Bodies fall from are as the Squares of the Velocities they acquire by falling; conſequently the Reſiſtance a Fluid gives to a Solid, againſt which it moves, is alſo as the Square of its Velocity. Now it matters not, as to the Reſiſtance, whether the Fluid moves againſt the Solid, or whether it be at Reſt, and the Solid moves in it; the Reſiſtance therefore which a Fluid gives to a Solid moving in it, is as the Square of the Velocity, with which it moves.

And

And this, in ſimilar Bodies of equal Magnitudes, is inverſely as their Denſities, or the Quantity of Matter they contain; for by how much the greater the Quantity of Matter in any Body is, ſo much the more eaſily does it overcome the Reſiſtance it meets with from the Fluid. Thus, we ſee the Reſiſtance of the Air has a much leſs Effect in deſtroying the Motion of an heavy Body, than of a light one which has the ſame Dimenſions.

IV. In ſimilar Bodies of equal Denſities, but different Magnitudes, the Retardation is inverſely as their homologous Sides. For the Reſiſtance Bodies meet with in a Fluid, is inverſely as the Quantities of Matter they contain (by the laſt), that is inverſely as the Cubes of their homologous Sides; and it is alſo directly as their Surfaces, becauſe 'tis by them that they move the Fluid out of its Place; that is, directly as the Squares of their homologous Sides; conſequently the Retardation is inverſely as their homologous Sides *.

Having given the fundamental Principles of *Hydroſtatics*, and ſhewn how Fluids, both compreſſible and incompreſſible, are diſpoſed to act upon each other, and upon Solids by their Preſſure, Motion, Elaſticity, and Reſiſt-

* Becauſe the inverſe Ratio of the Cubes of any Numbers being compounded with the direct Ratio of the Squares of the ſame, gives the inverſe Ratio of the Numbers themſelves

ance; I proceed now to account for ſome of the more remarkable Phænomena of Nature, in which they are in Part or altogether concerned: And this I deſign for the Subject of the following Diſſertations.

DIS-

DISSERTATION I.

Of Sound.

WHEN the Parts of an elaſtic Body are put into a tremulous Motion by Percuſſion or the like; ſo long as the Tremors continue, ſo long is the Air, included in the Pores of that Body, and likewiſe that which preſſes upon its Surface, affected with the like Tremors and Agitations: Now, the Particles of Air being ſo far compreſſed together by the Weight of the incumbent Atmoſphere, as their repulſive Forces permit, (as has been explained Chap. 3.) it follows, that thoſe, which are immediately agitated by the reciprocal Motions of the Particles of the elaſtic Body, will, in their Approach towards thoſe which lie next them, impel them alſo towards each other; and thereby cauſe them to be more condenſed, than they were by the Weight of the incumbent Atmoſphere, and in their Return will ſuffer them to expand themſelves again; whereby the like Tremors and Agitations will be propagated to the next; and ſo on, till having arrived at a certain Diſtance from the Body, the Vibrations ceaſe, being gradually deſtroyed by a continual ſucceſſive Propagation of Motion to freſh Particles of Air throughout their Progreſs.

Thus

Thus it is that Sound is communicated from a tremulous Body to the Organ of Hearing. Each Vibration of the Particles of the ſounding Body is ſucceſſively propagated to the Particles of the Air, till it reaches thoſe which are contiguous to the *Tympanum* of the Ear, (a fine Membrane diſtended acroſs it,) and theſe Particles in performing their Vibrations impinge upon the Tympanum, which agitates the Air included within it; and that being put into a like tremulous Motion, affects the auditory Nerve, and thus excites in the Mind the Senſation or Idea of what we call *Sound*.

Now ſince the repulſive Force of each Particle of Air is equally diffuſed around it every Way; it follows, that when any one approaches a Number of others, it not only repels thoſe which lie before it, in a right Line; but all the reſt, laterally according to their reſpective Situations: that is, it makes them recede every Way from itſelf, as from a Center: and, this being true of every Particle, it follows, that the aforeſaid Tremors will be propagated from the ſounding Body in all Directions, as from a Center: And farther, if they are confined for ſome Time from ſpreading themſelves by paſſing through a Tube or the like, will, when they have paſſed through it, ſpread themſelves from the End in every Direction. In like Manner, thoſe which paſs through an Hole in an Obſtacle they meet with

with in their Way, will afterwards ſpread themſelves from thence, as if that was the Place where they began; ſo that the Sound, which paſſes through an Hole in a Wall or the like, is heard in any Situation whatever, that is not at too great a Diſtance from it. Something analogous to this we may obſerve in the Motion of Waves upon the Surface of a Fluid, which are propagated equally through all Parts of the Surface in a Circle, though occaſioned not by a circular, but reciprocal Motion and Agitation of the Finger or any other Body in a ſtraight Line.

Since the repulſive Force, with which the Particles of Air act upon each other, is reciprocally as their Diſtances; (Chap. 3. §. 10.) it follows, that when any Particle is removed out of its Place by the Tremors of a ſounding Body, or the Vibrations of thoſe which are contiguous to it, it will be driven back again by the repulſive Force of thoſe towards which it is impelled, with a Velocity proportionable to the Diſtance from its proper Place; becauſe the Velocity will be as the repelling Force. The Conſequence of this is, that, let the Diſtance be great or ſmall, it will return to its Place in the ſame Time; (for the Time a Body takes up in moving from Place to Place will always be the ſame, ſo long as the Velocity it moves with is proportionable to the Diſtance between the Places.) The Time therefore

fore in which each Vibration of the Air is performed, depends on the Degree of Repulſion in its Particles: And ſo long as that is not altered, will be the ſame at all Diſtances from the tremulous Body; conſequently, as the Motion of Sound is owing to the ſucceſſive Propagation of the Tremors of a ſounding Body through the Air, and as that Propagation depends on the Time each Tremor is performed in, it follows, that the Velocity of Sound varies as the Elaſticity of the Air, but continues the ſame at all Diſtances from the ſounding Body.

And as the Velocity, with which Sound is propagated, depends on the Elaſticity of the Air, ſo it does alſo on its Denſity; for when the Denſity of the Air is augmented, while its Elaſticity remains the ſame *, a great Num-

* Perhaps it will not appear to every one, how the Denſity of the Air can be augmented without a proportional Increaſe of its Elaſticity; becauſe *cæteris paribus*, the nearer the Particles approach each other, the ſtronger is the Action of their repulſive Force.

But it is to be conſidered, that when the Air becomes colder, its Elaſticity is diminiſhed, and then the Particles are brought cloſer together by the Preſſure of the Atmoſphere, till they acquire an Elaſticity equal to what they had before; *viz.* ſuch as anſwers to the Preſſure they ſuſtain (Chap. 3 §. 2.) From hence we may infer, that the Propagation of Sound is ſlower in Winter than in Summer, when the Mercury in the Barometer is at the ſame Height; for the Preſſure of the Air being the ſame, its Elaſticity which depends upon it, is ſo too; but the Air is denſer by Reaſon of the Cold, and therefore its Vibrations ſlower.

ber

ber of Particles will move forwards and backwards in each Vibration; now, ſince we ſuppoſe the Cauſe by which they put each other into Motion (*viz.* their Elaſticity,) the ſame, they will each receive a leſs Degree of Velocity; and ſo the Vibrations will be performed in a longer Time, whence the Succeſſion of them will be ſlower, and the Progreſs of the Sound proportionably retarded *.

Whereas the undulatory Motion of the Air, which conſtitutes Sound, is propagated in all Directions from the ſounding Body; it will frequently happen, that the Air, in performing its Vibrations, will impinge againſt various Objects, which will reflect it back, and

* The Method of determining the Velocity with which Sound is propagated, is (by the Help of a ſhort Pendulum) to eſtimate the Time, which paſſes between ſeeing the Fire of a Gun at a Diſtance, and hearing the Report. Its great Velocity makes it difficult to be determined exactly; accordingly Authors differ much in their Accounts. The moſt accurate Obſervers Dr. *Halley* and Dr. *Durham* have found it to be about one Thouſand one Hundred and Forty two Feet, which is almoſt a Quarter of a Mile, in a Second.

The uſual Experiments to prove that the Air is neceſſary for the Propagation of Sound, are ſuch as theſe. A ſmall Bell, being put into the Receiver of the Air-Pump, may be heard at a conſiderable Diſtance, before the Air is exhauſted out of it; but when the Air is much rarified by exhauſting, can ſcarcely be heard at all. When the Air is condenſed, the Sound is augmented in Proportion to the Condenſation. Theſe Experiments do not only ſucceed in forced Rarefactions and Condenſations, but in ſuch alſo as are Natural; Sound being obſerved to be much weaker on the Tops of high Mountains, where the Air is leſs condenſed by the Weight of the incumbent Atmoſphere, than in the Valleys below.

ſo cauſe new Vibrations the contrary Way; now, if the Objects are ſo ſituated, as to reflect a ſufficient Number of Vibrations back (*viz.* ſuch as proceed different Ways) to the ſame Place, the Sound will be there repeated, and is called an *Echo* *. And, the greater the Diſtance of the Objects is, the longer will be the Time, before the Repetition is heard. And when the Sound in its Progreſs meets with Objects, at different Diſtances, ſufficient to produce an Echo, the ſame Sound will be repeated ſeveral Times ſucceſſively, according to the different Diſtances of thoſe Objects from the ſounding Body; which makes what is called a *repeated* Echo.

If the Vibrations of the tremulous Body are propagated through a long Tube, they will be continually reverberated from the Sides of the Tube into its Axis, and by that means prevented from ſpreading, till they get out of it; whereby they will be exceedingly encreaſed and the Sound rendered much louder than it would otherwiſe be †.

* In *Woodſtock* Park near *Oxford*, there is an Echo, which repeats diſtinctly ſeventeen Syllables by Day, and twenty by Night. See *Plot*'s Natural Hiſtory of *Oxfordſhire*.

The Reaſon, why it repeats more Syllables by Night, than by Day, is becauſe the Air, being colder at that Time, is more denſe; and therefore the Return of the firſt Vibrations being ſlower, gives Time for the Repetition of more Syllables.

† This is the Caſe in the *Stentorophonic* Tube or Speaking-Trumpet.

The Difference of *Muſical* Tones depends on the different Number of Vibrations communicated to the Air, in a given Time, by the Tremors of the ſounding Body; and the quicker the Succeſſion of the Vibrations is, the acuter is the Tone, and *è contra*.

A muſical Chord performs all its Vibrations, whether great or ſmall in the ſame Time. For, if a String is ſtretched between two Pins, and a Force is applied to the middle Point, to draw it out of its rectilineal Situation; it is found by Experiment, that the Diſtance (if it be ſmall) to which it is drawn, is as the Force applied; conſequently the Velocity, with which it returns, when left to itſelf, will be as the Space it has to move over; it will therefore perform all its Vibrations in the ſame Time: This is the Reaſon why the ſame Chord,

Trumpet. See *Kircher* de Re Muſica. Lib. 9. Par. 4. *Ode* Philoſ. Natur. Princip. p. 293.

Upon this Principle it is, that Sound is conveyed from one Side of a *Whiſpering*-Gallery to the oppoſite one, without being perceived by thoſe who ſtand in the Middle The Form of a Whiſpering-Gallery is that of a Segment of a Sphere, or the like arched Figure; and the Progreſs of the Sound through it may be illuſtrated in the following Manner

Let ABC (*Fig.* 14.) repreſent the Segment of a Sphere; and ſuppoſe a low Voice uttered at D, the Vibrations expanding themſelves every Way, ſome will impinge upon the Points E, E, *&c.* from thence be reflected to the Points F, from thence to G, and ſo on, till they all meet in C; and by their Union there cauſe a much ſtronger Sound, than in any other Part of the Segment whatever, even at D the Point from whence they came.

however ſtruck, produces the ſame Note. It is alſo found by Experiment, that when Strings of equal Diameters, but different Lengths, are equally ſtretched, the longer they are, ſo much the leſs Weights will draw them from their rectilineal Situation to the ſame Diſtance; the Forces therefore by which they return are leſs, and the Times of their Vibrations longer.

When two Chords preform their Vibrations in equal Times, the Tone produced is called an *Uniſon*. If one performs two, while the other one; 'tis an *Octave*. If one three, while the other two; 'tis a *Fifth*. If one three, while the other four; 'tis called a *Fourth*, &c.

To make an Uniſon Sound, it is not neceſſary, that the Vibrations of the two Strings ſhould actually concur, but only that they ſhould be performed in equal Times; ſo that they would always concur, if they began at the ſame Inſtant. For the Ear perceives not the ſingle Vibrations diſtinctly, but only finds that Difference, which proceeds from the Intervals of Time, that paſs between them *.

* Upon theſe Principles we may account for that remarkable Phænomenon in *Muſic*, that an intenſe Sound being raiſed, either with the Voice or a ſonorous Body, another ſonorous Body near it and in Uniſon with it, will thereby be made to ſound. For the Vibrations of the Air, which correſpond to the Tremors of the firſt ſounding Body, agreeing exactly, in Point of Time, with thoſe, which are capable of being given to the other

other Body at Uniſon with it; when they have by their firſt Impulſe communicated a ſmall Degree of Motion to it, will, by conſpiring with it as it moves forwards and backwards, continually increaſe its Motion, till it becomes ſenſible. The contrary happens in Strings which are in Diſcord with each other; for in this Caſe, though the firſt Vibration of one may give Motion to the other, yet their Vibrations not being performed in equal Times, the ſecond will come *unſeaſonably*, *i. e.* when the other is moving the contrary Way, and obſtruct its Motion. It is farther obſervable, that in two Strings, one of which vibrates twice, while the other once; if the firſt be ſounded, the two Extreams of the other will each ſound an Uniſon with it, while the middle Point remains at Reſt. So if one vibrates thrice, while the other once, the laſt will be divided into three Parts each of which will ſound an Uniſon with it, and the two Points between thoſe Parts will remain at Reſt. For otherwiſe that which vibrates twice, while the other once, muſt neceſſarily interfere with it at every ſecond Vibration; and that which vibrates thrice, while the other once, would interfere with it at every third; ſo that it would not be put into a ſufficient Motion to produce a Sound. But, when it is divided by the quieſcent Points, it becomes ſo many Strings at Uniſon with the former, each of which eaſily receives its Vibrations from thence.

From hence likewiſe it is, that, if we take two or three drinking Glaſſes, and put ſome Water or other Fluid into each of them, and place them near to each other, taking Care to fill them, to ſuch Heights, that (when ſtruck) their Tones ſhall be in Uniſon; and then, if we ſlide the Finger along the Brim of one of the Glaſſes, preſſing pretty ſtrongly upon it, (which will cauſe it to ſound) we ſhall ſee the Surface of the Fluids in the other Glaſſes begin to tremble; which ſhews that the Vibrations of the firſt Glaſs cauſe the like in the other at Uniſon with it; though not perhaps in a Degree ſufficient to produce a Sound, ſtrong enough to be heard diſtinctly from the former.

Thus it is that ſome Perſons are able to break a drinking Glaſs by a Tone of their Voice at Uniſon with it. They firſt try the Tone of the Glaſs by ſtriking it, then applying their Mouth near to the Brim of it, ſound the ſame Note with their Voice: this ſets the Glaſs a trembling; they then continually raiſe their Voice, ſounding ſtill the ſame Note; this encreaſes the Tremors of the Glaſs, which by that Means (if it is not too ſtrong) is broke in Pieces.

The

The Effect of *Muſic* upon Perſons bit with the *Tarantula*, (if the Accounts we have of it from Abroad may be credited) is very ſurpriſing. A Perſon bit with the *Tarantula* after ſome Time loſes both Senſe and Motion, and dies if deſtitute of Help. The moſt effectual Remedy is *Muſic*. The Muſician tries Variety of Airs, till he hits upon one that affects the Patient, who upon that begins to move by Degrees; firſt keeps Time with his Fingers, Arms, and Legs, afterwards is violently agitated in every Part of his Body; and then leaps up, begins to dance, and increaſes in Activity every Moment; till after five or ſix Hours, being very much fatigued, he is put to Bed and left to ſweat. The next Day the ſame Air brings him out of Bed for a new Dance. Which Exerciſe being thus continued, the Diſtemper is abated in the Space of four or five Days, the Effects of the Bite being in ſome Meaſure carried off by Sweat, and the Patient begins then to recover his Senſe and Knowledge by little and little.

The Reaſon why the Patient is thus affected by the *Muſic*, is becauſe the Nerves of his Body are ſo diſpoſed in that Diſtemper, as eaſily to be agitated by the Vibrations which are occaſioned by the Principle and ſtronger Notes of what is played.

See on the Subject of this Diſſertation, Philoſoph. Tranſact. No. 134, 243, 302, 313, 319, 337. Hiſt. de l'Acad. 1702, 1708. *Grew*'s Coſmolog. Sacr. Book I. Chap. 5. *Mead* upon Poiſons, p. 59. *Keil*'s Anatomy, p. 214. *Baglivi* Prax. Medic. Diſſert. I. *Bellini* de Urinis & Pulſibus, &c. ſub fine Capitis de Mania.

DIS-

DISSERTATION II.

Of Capillary Tubes.

BY a *Capillary Tube* is generally underſtood a Glaſs Pipe; the Diameter of whoſe Bore is at moſt but about one tenth of an Inch; though any Tube whoſe Cavity does not exceed that Magnitude, may be ſo called.

The Phænomena of Capillary Tubes being ſuch as contradict a known Law in *Hydroſtatics*, viz. *that a Fluid riſes in a Tube to the ſame Height with the Level of its Source* *; and likewiſe of Affinity with the Aſcent of the Sap through the Stems of Plants for the Nouriſhment of their Fruit, and with divers other Operations of Nature: it has been thought of no ſmall Moment in Philoſophy to find out and eſtabliſh their true Cauſe; which after numerous Experiments and ſeveral Conjectures about it, is found to be no other than the Attraction of Coheſion; by which ſmall Particles of Matter mutually adhere together and form larger Bodies †. I ſhall lay down

* See Chap. I §. 9. Caſe 4 in the Notes.

† See *Hauksbee*'s and *Power*'s Experiments. *Muſſchenbroeck* 4to Edit. Philoſoph. Tranſact. No. 355. Mem. de l'Acad. 1705, 1714, 1722, 1724. With others referr'd to in Quæſtiones Philoſoph.

the

the ſeveral Phænomena, as ſo many Matters of Fact; and ſubjoin to each a Solution from that Cauſe. In Order to which, it may not be improper to premiſe the following Conſideration by Way of *Lemma*.

Let us ſuppoſe the Veſſel ABCD (*Fig.* 15.) filled with a Fluid to the Height LM, and let it be conceived as divided into the equal Portions EFGH, GHIK, IKLM, *&c.* farther, let it be ſuppoſed, that each Particle of Matter in the inner Surface of the Veſſel, has a Sphere of Attraction, whoſe Semidiameter is equal to the Breadth of three of thoſe Portions; that is to ſay, that the Attraction of the Particle M reaches upwards as far as F, and downwards as far as S; and that of the Particle O, upwards as far as H, and downwards as far as U; and ſo of all the reſt quite round the Tube. From hence it will follow, that every Particle of the inner Surface of the Veſſel, which lies between EF and RS conſpires in endeavouring to raiſe the Fluid towards AB the Top of the Veſſel; and that the Fluid is not affected by any other. For Inſtance, the Particle S, and all below it, will attract downwards three Strata of the Fluid (ſuch as are contained in three equal Diviſions of the Veſſel) from above, and as many upwards from below; and therefore will have no Effect at all in raiſing or depreſſing the Fluid. But the Particle Q will attract only two Strata down-

downwards; becauſe there are no more above it, and three upwards, and therefore will in ſome Meaſure tend to raiſe the Fluid; ſo the Particle O will attract but one downwards and three upwards; the Particle M none downwards, and three upwards; the Particle K two upwards, and H only one: All which may clearly be ſeen by their Situations in the Figure with Reſpect to the Surface of the Fluid. Therefore in every Veſſel, where there is a mutual Attraction between the Fluid it contains and the Particles of which it is compoſed, there will be a certain Number of Particles diſpoſed around it in Form of a broad Periphery or Zone as repreſented by AB; (*Fig.* 16;) half of which lies above the Surface of the Fluid and half below it, that will tend to make it riſe towards the Top. This being underſtood, the following Phænomena will not be difficult *.

* I have been the more particular in explaining this *Lemma*, becauſe it is not a bare *Periphery* of no Breadth, to which the Aſcent of the Fluid is owing, but a *Zone* or *Cingulum* of Particles diſtended equally in Breadth both ways from the Surface of the Fluid; and becauſe it is upon the Breadth of this, that ſome of the following Solutions depend. As to the Thickneſs of it, that undoubtely is equal to the Semidiameter of the Sphere of Attraction in the Particles of the Veſſel; and therefore Veſſels, whoſe Sides are of different Thickneſſes (provided thoſe Thickneſſes be leſs than that Semidiameter) muſt have different Effects upon the ſame Fluid, though no one has as yet been ſo accurate as to obſerve it. The Reaſon, why a Fluid will not riſe in a large Veſſel, as well as in one that is Capillary, is becauſe the Attraction of its Particles does not reach far enough into the Middle of the Veſſel; and therefore

I. Let there be two Capillary Tubes AB and CD (*Fig.* 17.) open at both Ends; and having their lower Orifices A and C immerged below the Surface of the Water contained in the Veſſel FGHI: The Water will immediately riſe up in each Tube above the Surface of that in the Veſſel, beginning with a ſwift Motion, which will gradually decreaſe; till as much Water has entered the Tubes, as they are able to raiſe: And the Heights to which the Water will riſe in them, will be reciprocally as their Diameters.

That the Water ought to riſe in both Tubes is an immediate Conſequence of the foregoing *Lemma*; becauſe the Column of Water within the Tube is rendered lighter than an equal Column on the outſide, as being attracted upwards by a Portion of the interior Surface of the Veſſel; and therefore will riſe till it becomes as much longer than the external ones as it is made lighter; that the *Æquilibrium*, which was deſtroyed by the Attraction of the Tube, may be reſtored by the Weight of the Column. The Reaſon that the Velocity with which it riſes, ought conſtantly to decreaſe, is becauſe the heavier the Column is, the leſs is the Effect of the Attraction, which is always the ſame in a Tube of the ſame Diameter.

it only riſes about the Sides, ſtanding higher there than in the Middle: As may be ſeen in a Drinking-Glaſs, when a Quantity of Water is put into it, ſomewhat leſs than is ſufficient to fill it.

And

Fig. 11. P. 25.

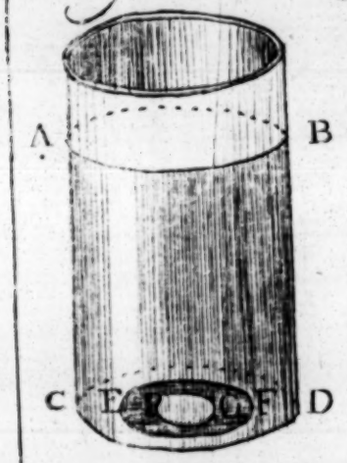


Fig. 12. P. 28.

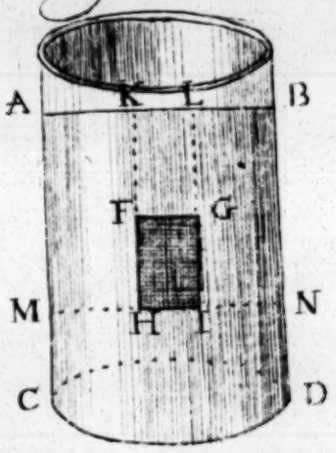


Fig. 13. P. 29

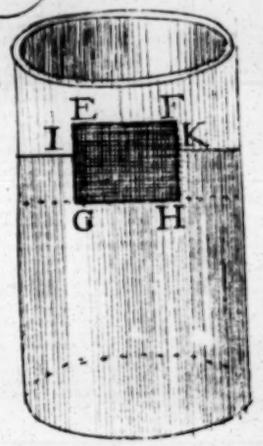


Fig. 14. P. 53

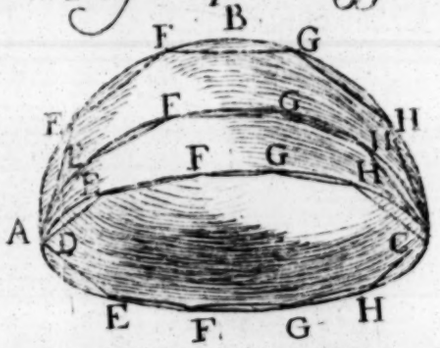
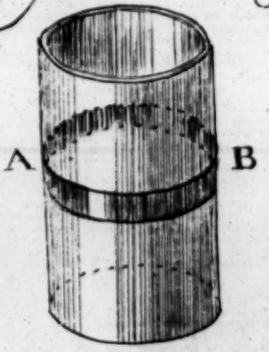


Fig. 15. P. 58.

Fig. 16. P. 59



And laſtly, the Heights to which the Water riſes in them, will be reciprocally as their Diameters; for then the Quantities raiſed will be directly as the Diameters *; but the Peripheries that raiſe them, (being always of the ſame Breadth and having their Lengths equal to the Circumferences of the Tubes,) are as thoſe Diameters; the Quantities of Water therefore, being in the ſame Ratio, are as the Peripheries, *i. e.* as the Cauſes by which they are raiſed.

II. If the Tubes, before they are immerged in the Water, are filled to greater Heights, than thoſe to which it would naturally riſe in them; and then have their lower Orifices immerged in Water, the Water will ſubſide till it ſtands in each at the ſame Height to which it would have riſen; but, if they are held in a perpendicular Poſition without being immerged, the Water will not ſubſide in the Tubes *quite* ſo far.

The Reaſon why the Water in the Tube when its lower Orifice is immerged, ſubſides to the ſame Height it would have riſen to, had

* The Heights to which the Water riſes, being in a reciprocal Ratio of the Diameters; and the Contents of Cylindrical Tubes being in a direct Ratio of their Heights, and of the Squares of their Diameters; the Quantities of Water raiſed in this Caſe will be in a reciprocal Ratio of the Diameters, and a direct one of the Squares of the ſame. Now theſe two Ratio's being compounded together, give the direct one of the Diameters themſelves; becauſe the ſimple reciprocal Ratio deſtroys one of thoſe, which are contained in the direct one of the Squares.

the Tube been immerged when empty, is becauſe the Column is ſuſpended in one Caſe by the ſame Cauſe, by which it is raiſed in the other; but when the Tube full of Water is held erect, without being immerged, it will not ſubſide *quite* ſo far; becauſe the lower End of the Tube, which the Water leaves behind it as it drops out, attracts it the contrary Way; ſo that the Column in this Caſe is ſuſpended not only by the inner Surface of the Tube at the Top, but alſo by its lower End; and therefore a greater Quantity of Water is ſuſpended than in the former Caſe.

III. If a Tube, having its lower Orifice immerged in Water, be held obliquely, it will raiſe the Water to the ſame perpendicular Height, as when held erect.

For ſince Fluids preſs according to their perpendicular Heights, the Weight of the Column raiſed will not be proportionable to the attractive Force of the Tube, till it has arrived at the ſame perpendicular Height, to which it would have roſe, if held erect.

IV. If a Tube, when the Water is riſen into it to its wonted Height, is laid in an Horizontal Situation, the Water will move towards the Middle of the Tube, leaving the End which was immerſed a little behind.

The Solution of this Phænomenon depends on what was obſerved in the Lemma about the Breadth of the attracting Periphery, and its

its being equally ſituated on each Side the Surface of the Water; for from thence it follows, that if the Water ſhould not run from the full End of the Tube, after it has laid in an Horizontal Situation, but remain contiguous to it; that End of the Column of Water would be attracted only by ſuch a Portion of a Periphery as lies within its Surface at that End; becauſe the End of the Tube coinciding with the Surface, the other Half of the Periphery is wanting. Whereas, at the other End of the Column, there is a Periphery whoſe Breadth is entire; which overpowering the other, cauſes the Water to move towards the Middle of the Tube, till as much Periphery is left behind, as can at once affect the Water by the Attraction of its Particles; after which the Water being attracted equally each way, remains at Reſt.

V. Let there be a Tube (*Fig.* 18.) conſiſting of two Parts DR and RCK, of different Diameters; it follows from what has been ſaid, that DR the ſmaller Part of the Tube, is able to raiſe Water higher than the other: Let then the Height to which the larger would raiſe it be TF, and that to which it would riſe in the leſſer (was it continued down to the Surface of the Fluid) be XL. If this compound Tube be filled with Water and the larger Orifice CK be immerſed in the ſame Fluid the Surface of the Water will ſink no farther

farther than XL; the Height to which the leſſer Part of the Tube would have raiſed it.

But if the Tube be inverted as in *Fig.* 19. and the ſmaller Orifice XL be immerſed, the Water will run out till the Surface falls to TF; the Height to which the larger Part of the Tube would have raiſed it. The Size of the lower Part making no Alteration in the Height, at which the Fluid is ſuſpended in either Caſe.

In order to account for theſe Phænomena, it muſt be conſidered, that when a Body is ſo diſpoſed, that its different Parts ſhall move with different Degrees of Velocity, the greater Proportion the Velocity of that Part to which a moving Power is applied, bears to that of the reſt; ſo much the more effectual is the Power in moving that Body; or that the ſame Power applied to different Parts, will be equivalent in Effect to different Powers applied to the ſame Part: As is the known Caſe of the *Lever*, and all the other *Mechanical* Powers.

Now let us conceive the Tube DR (*Fig.* 18.) continued down to HI, and let it be ſuppoſed at preſent that the Fluids contained in the Tube XLHI and the compound one XLKC, are not ſuſpended by the Periphery at L, but that they preſs upon their reſpective Baſes HI and CK. Let it farther be ſuppoſed that theſe Baſes are each of them moveable and

and that they are raiſed up or let down with equal Velocities; then will the Velocity with which XL the uppermoſt Stratum of the Fluid XLCK moves, exceed that of the ſame Stratum, conſidered as the uppermoſt of the Fluid in the Tube XLHI, as much as the Tube RCK is wider than DR (by the *Lemma* Chap. 1. §. 9.) that is, as much as the Space MNKC exceeds XLIH; conſequently by the foregoing Obſervation, the Effect of the attracting Periphery XL, as it acts upon the Fluid contained in the Veſſel XLCK, exceeds its Effect, as it acts upon that in XLHI, in the ſame Proportion. Since therefore it is able (*ex Hypoth.*) to ſuſtain the Weight of the Fluid XLHI by its natural Power, it is able under this *Mechanical* Advantage, to ſuſtain the Weight of as much, as would fill the Space MNKC: But the Preſſure of the Fluid XLCK is equal to that Weight, as having the ſame Baſe and an equal Height (Chap. 1. §. 9.) its Preſſure therefore, or the Tendency it has to deſcend in the Tube, is equivalent to the Power of the attracting Periphery XL, for which Reaſon it ought to be ſuſpended by it.

Again, the Height (*Fig.* 19.) at which the attracting Periphery in the larger Part of the Tube is able to ſuſtain the Fluid is no greater than NF, that to which it would have raiſed it, had the Tube been continued down to MN. For here the Power of the attracting

ing Periphery acts under a like *Mechanical* Diſadvantage; and is thereby diminiſhed in Proportion to the Capacity of the Tube TFNM to that of HIXL; becauſe, if the Baſes of theſe Tubes are ſuppoſed to be moved with equal Velocities, the Riſe or Fall of the Surface of the Fluid TFXL would be ſo much leſs than that of TFMN. And, whereas the attracting Periphery TF is able by its natural Power to ſuſpend the Fluid only to the Height NF in the Tube TFMN; it is in this Caſe able to ſuſtain no greater Preſſure than what is equal to the Weight of the Fluid in the Space HIXL: but the Preſſure of the Fluid TFXL which has equal Height and the ſame Baſe with it, is equal to that Weight; and therefore is a juſt *Æquipondium* to the attracting Power.

VI. From hence we may clearly ſee the Reaſon, why a ſmall Quantity of Water put into a Capillary Tube, which is of a Conical Form and laid in an Horizontal Situation, will run towards the narrower End. For let AB (*Fig.* 20.) be the Tube, CD a Column of Water contained within it; when the Fluid moves, the Velocity of the End D will be to that of the End C reciprocally as the Cavity of the Tube at D, to that at C (by the *Lemma* Chap. 1. §. 9.) that is, reciprocally as the Square of the Diameter at D, to the Square

of

of the Diameter at C*; but the attracting Periphery at D is to that at C, in the ſimple Ratio of the Diameter at D, to the Diameter at C. Now, ſince the Effect of the Attraction depends, as much upon the Velocity of that Part of the Fluid where it acts, as upon its natural Force, its Effect at D will be greater than at C; for though the Attraction at D be really leſs in itſelf than at C, yet its Loſs of Force upon that Account, is more than compenſated by the greater Velocity of the Fluid in that Part: the Fluid will therefore move towards B.

VII. From hence likewiſe it follows, that if a Veſſel as ABC (repreſented *Fig.* 21.) of any Form whatever, have its upper Part drawn out into a Capillary Tube as B; and if this Veſſel is filled with Water, and have its lower Orifice placed on FG the Surface of the ſame Fluid; then the Water will remain ſuſpended in the Veſſel, provided the Capillary at the Top be ſmall enough, (was it continued down to the Bottom) to raiſe the Fluid to the Height B. Becauſe, by Propoſition the fifth, the lower Part of the Tube makes no Alteration in the Height, at which the Capillary B is able to ſuſtain the Fluid.

VIII. And if the ſame Veſſel be filled only to the Height DE (*Fig.* 22.) and a Drop of

* 12. *El.* 2.

Water be put into the Capillary at B, (the intermediate Part BDE being full of Air) the Water will continue ſuſpended at the Height DE.

For, although the Fluid ACDE is not in Contact with the Drop of Water in the Capillary Tube, and therefore not immediately ſupported by it; yet the Preſſure of the Atmoſphere upon the Surface FG, and againſt the upper Part of the Drop in the Capillary B keeps the Fluid ADEC, and the Drop and the intermediate Air from ſeparating, juſt as in the former caſe the Attraction of Coheſion in the Particles of the Water prevented a Separation between that in the Veſſel and that in the Capillary. Conſequently, as the Water in the Capillary was able in the former Caſe to ſuſtain as much Fluid as the Veſſel could contain, it is now ſufficient to ſuſtain the Fluid ADEC *.

IX. Let there be a Capillary Siphon, as that repreſented *Fig.* 23, 24 or 25, and let EF be the Height, to which Water might be raiſed by a Periphery equal to that at A. Now, ſince

* This happens quite otherwiſe in Vacuo, becauſe the Preſſure of the Air, which as it where connects the Drop with the Water ADEC, being wanting, it immediately falls for Want of a Support. Whereas the former Phænomenon equally ſucceeds in Vacuo; which ſhews that the Parts of the Fluid in the Veſſel are connected with each other, and with that in the Capillary by their own mutual Attraction of Coheſion, there being nothing elſe whereby they can be ſupported.

(as

(as was obſerved §. 2.) the lower End of a Tube when it is not immerged, cauſes a longer Column to be ſuſpended than otherwiſe would be; that is, it ſupports a ſhort Column beſides that which is ſuſtained by the attracting Periphery; let HI be the Height of ſuch a Column as might be ſuſpended by the End C: then, if any of thoſe Tubes are filled with Water, and held as in the Figure (neither End being immerged) the Fluid will run out of the Tube at C, if CD the Difference of the Legs exceeds EF and HI added together, otherwiſe not.

For the Column AB is a Counterpoiſe to BD, being of the ſame perpendicular Height; and therefore it is only the Weight of the Colum CD, which determines the Fluid to move; unleſs that Weight therefore exceeds the Force of the attracting Periphery at A (which the Fluid AB muſt leave in riſing up the Tube) and alſo what may be ſupported by the End C, that is, (*ex Hypoth.*) two Columns whoſe Heights are EF and HI, it cannot run out at C; otherwiſe it will, as being deſtitute of a ſufficient Support.

X. If the End A is immerged in Water and the other not (ſuppoſing the Tube full as before,) it will run out at C, though CD the Difference of the Legs, only exceeds HI. For then the Attraction at A ceaſes, and there is nothing to ſupport the Column CD, but the

Power the End C has to prevent Drops from falling off it.

XI. Again, if the End C is immerged in Water, (and the other not) it will run out at C, if CD exceeds EF, otherwiſe not.

For in this Caſe, there is nothing to ſupport the Column CD, but the attracting Periphery at A, whoſe Power is ſuppoſed able to raiſe a Column as EF, and no more.

XII. And, if both Ends are immerſed (the Tube being ſuppoſed full as before) the Water will run out at the lower, which ever it is. For then the Attraction of both Ends ceaſes; and the longer Column over-balancing the ſhorter, the Fluid is determined thereby to run out at the lower End.

XIII. If either of the Tubes (*Fig.* 23 or 24.) are ſmall enough to raiſe the Water from A to B, and if the Orifice A is immerged, the Fluid will riſe to B, paſſing on to C, where it will run out or be ſuſpended according to the foregoing Caſes: but if the Periphery at G (*Fig.* 25.) is ſuch as would not ſupport the Fluid higher than AM, it will ſtop when it comes at G, and only the Part AEG will be filled with it.

For that Fluid which has paſſed B aſſiſts by its Weight the attracting Periphery in raiſing the Column AB, and therefore it runs down to C. But, if when it comes to G, the Periphery there is not able to ſupport more than AM the

the Difference of the Legs AB and BG, the Fluid muſt neceſſarily ſtop there; ſince BG is no more than a Counterpoiſe to MB, and AM is ſuppoſed to be as much as the Periphery at G can ſuſtain.

XIV. Tho' a Capillary Tube be ſhorter than the Height to which its attracting Periphery is able to raiſe a Fluid, *v. g.* tho' the Tube AB (*Fig.* 26.) be ſmall enough (was it of ſufficient Length) to raiſe Water as high as C; yet when the End A is immerged, the Fluid will not run out at B, but only be ſuſpended at that Height.

For when the Fluid is riſen as high as B, it has then no more Periphery above it, to attract it any farther; and if it was forced up a little higher, it would be attracted back again by the End *.

XV. The Aſcent of different Fluids in the ſame Tube is various. *Muſſchenbroek* has found, that in a Tube in which Water will riſe to the Height of twenty ſix Lines, Oyl of Wormwood will riſe but eighteen or nineteen, whereas Urine will riſe thirty three or thirty four.

* Hence we ſee the Abſurdity of ſuppoſing that a Fluid may be made continually to flow from a lower Place to an higher by a Capillary Tube, as ſuch; for whether the Tube be of ſuch Form, as is repreſented Fig. 23, 24, 25, or 26. The Fluid will always ſtop when it comes at the higher End; becauſe the Attraction is then in a Direction contrary to its Motion, and the Weight of the whole Fluid, if the Tube is ſtraight, or of ſo much as is contained in DC the Difference of the Legs, if it be crooked, is likewiſe an Impediment to it.

The

The Reaſon of which is, becauſe ſome Fluids are attracted more ſtrongly by Glaſs, than others are. Mercury exhibits Phænomena juſt the Reverſe of the former; for if the End of a Capillary Tube be immerſed below the Surface of that Fluid, it will not riſe in the Tube to a Level with that on the outſide. This is becauſe the Particles of Mercury attract each other more forcibly than they are attracted by thoſe of Glaſs *.

* See *Jurin*'s Diſſert. Philoſoph. Tranſ. No. 363.
According to *Muſſchenbroeck* the Length of the upper Part of a Tube, which is above the Height to which it is able to raiſe a Fluid, conduces ſomething towards the raiſing it; and therefore in a longer Tube a Fluid riſes higher than in one of the ſame Dimenſions that is ſhorter; and if a Tube, with ſo much Fluid contained in it, as it is able to raiſe, be laid in an Horizontal Situation, the Fluid will run to the Middle of it. But of this I have had no Experience: 'Tis poſſible that ingenious Profeſſer though very accurate in making Experiments, might herein be deceived. He acknowledges, (Experiment the fifteenth,) that it ſometimes happens otherwiſe.

Other Authors beſides thoſe already referred to, that have treated on this Subject, are *Boyle* Exper. Phyſ. Mech. Exp 9 *Sturmius* Colleg. Cur. Tentam. 8. *Bernoulli* Gravit. Æth. *Hooke* Microgr. Obſer. 6. *Leeuwenhoek* Continuat. Arcan. Nat. Epiſt. 131. *Sinclaire* Art. Gravit.

DIS-

DISSERTATION III.

Of the Origin of Fountains.

MANY have been the Conjectures of Philoſophers concerning the Origin of Fountains; and great Pains have been taken both by the Members of the Royal Society, and thoſe of the Academy of Sciences at *Paris*, in order to aſcertain the true Cauſe of it. It was ARISTOTLE's Opinion, and held by moſt of the ancient Philoſophers after him, that the Air contained in the Caverns of the Earth, being condenſed by Cold near its Surface, was thereby changed into Water; and that it made its Way through, where it could find a Paſſage. But we have no Experience of any ſuch Tranſmutation of Air into Water.

Thoſe, who imagine that Fountains owe their Origin to Waters brought from the Sea by ſubterraneous Ducts, give a tolerable Account how they loſe their Saltneſs by Percolation as they paſs through the Earth; but find great Difficulty in explaining by what Power the Water riſes above the Level of the Sea, to near the Tops of Mountains, where Springs generally abound; it being contrary to

to the Laws of *Hydroſtatics*, that a Fluid ſhould riſe in a Tube above the Level of its Source. However, they have found two Ways, whereby they endeavour to extricate themſelves from this Difficulty. The one is that of DES CARTES, who imagines, that after the Water is become freſh by Percolation, it is raiſed out of the Caverns of the Earth in Vapour towards its Surface; where meeting with Rocks near the Tops of Mountains in the Form of Arches or Vaults, it ſticks to them, and runs down their Sides, (like Water in an Alembic) till it meets with proper Receptacles, from which it ſupplies the Fountains. Now, this is a mere *Hypotheſis* without Foundation or Probability; for in the firſt Place, we know of no internal Heat of the Earth to cauſe ſuch an Evaporation; or if that were allowed, yet 'tis quite incredible, that there ſhould be any Caverns ſo ſmooth, and void of Protuberances, as to anſwer the Ends of an Alembic, in collecting and condenſing the Vapours together, in every Place where Fountains ariſe. There are others (as VARENIUS, *&c.*) who ſuppoſe that the Water may riſe through the Pores of the Earth, as through Capillary Tubes by Attraction; but hereby they ſhew, that they are quite unacquainted with what relates to the Motion of a Fluid through ſuch Tubes. For when a Capillary Tube opens into

to a Cavity at its upper End, or grows larger and larger, ſo as to ceaſe to be Capillary at that End; the Water will not aſcend through that Tube into the Cavity, or beyond where the Tube is Capillary; becauſe there the Force of Attraction is exerted the contrary Way: Nay, if the Cavity is continually ſupplied with Water, it will be attracted into the Capillary Tube, and run down it, as through a Funnel, if the lower End is immerged in the ſame Fluid, as in this Caſe it is ſuppoſed to be *.

It has been a generally received Opinion, and much eſpouſed by MARRIOTTE (a diligent Obſerver of Nature,) that the Riſe of Springs is owing to the Rains and melted Snow. According to him, the Rain-Water which falls upon the Hills and Mountains, penetrating the Surface, meets with Clay or Rocks contiguous to each other, along which it runs, without being able to penetrate them, till being got to the Bottom of the Mountain, or to a conſiderable Diſtance from the Top, it breaks out of the Ground and forms Springs.

In Order to examine this Opinion, Mr. PERRAULT, DE LA HIRE, and D. SIDELEAU endeavoured to make an Eſtimate of the Quantity of Rain and Snow, that falls in the Space of a Year, to ſee whether it would be ſufficient to afford a Quantity of Water, equal to

* See the foregoing Diſſertation, Sect. 14.

that which is annually diſcharged into the Sea by the Rivers. The Reſult of whoſe Inquiries was, that the Quantity of Rain and Snow which fell in a Year into a Cylindrical Veſſel, would fill it (if ſecured from evaporating) to the Height of about nineteen Inches. Which Quantity D. SIDELEAU * ſhewed, was not ſufficient to ſupply the Rivers; for that thoſe of *England*, *Ireland*, and *Spain* diſcharge a greater Quantity of Water annually, than the Rain, according to that Experiment, is able to ſupply. Beſides which, another Obſervation was made by them at the ſame Time, *viz.* that the Quantity of Water raiſed in Vapour one Year with another, amounted to about Thirty two Inches, which is thirteen more than falls in Rain: A plain Indication, that the Water of Fountains is not ſupplied by Rains and melted Snow.

Thus, the true Cauſe of the Origin of Fountains remained undiſcovered, till Dr. HALLEY in making his Celeſtial Obſervations upon the Tops of the Mountains at St. *Helena*, about eight Hundred Yards above the Level of the Sea, found that the Quantity of Vapour which fell there (even when the Sky was clear) was ſo great that it very much impeded his Obſervations, by covering his Glaſſes with Water every half Quarter of an Hour; and upon that

* Memoirs of the Royal Academy of Sciences for the Year 1632.

at-

attempted to determine by Experiment the Quantity of Vapour, exhaled from the Surface of the Sea, as far as it ariſes from Heat; in order to try, whether that might be a ſufficient Supply for the Water continually diſcharged by Fountains. The Proceſs of his Experiment was as follows. He took a Veſſel of Water ſalted to the ſame Degree with that of Sea-Water, in which he placed a Thermometer; and by means of a Pan of Coals, brought the Water to the ſame Degree of Heat, which is obſerved to be that of the Air in our hotteſt Summer: This done, he affixed the Veſſel of Water with the Thermometer in it, to one End of a Pair of Scales, and exactly counterpoiſed it with Weights on the other. Then, at the End of two Hours, he found by the Alteration made in the Weight of the Veſſel, that about a ſixtieth Part of an Inch of the Depth of the Water, was gone off in Vapour; and therefore in twelve Hours, one tenth of an Inch would have gone off. Now this accurate Obſerver allows the *Mediterranean Sea* to be forty Degrees long and four broad; (the broader Parts compenſating for the narrower;) ſo that its whole Surface is one Hundred and ſixty ſquare Degrees; which according to the Experiment muſt yield at leaſt five Thouſand two Hundred and eighty Millions of Tons. In which Account, no Regard is had to the Wind, and the Agitation of the

Surface of the Sea; both which undoubtedly promote the Evaporation.

It remained now, to compare this Quantity of Water, with that, which is daily conveyed into the ſame Sea by the Rivers. The only Way to do which, was to compare them with ſome known River; and accordingly he takes his Computation from the River *Thames*, and to avoid all Objection, makes Allowances, probably greater than what were abſolutely neceſſary.

The *Mediterranean* receives the following conſiderable Rivers, *viz.* the *Iberus*, the *Rhone*, the *Tibur*, the *Po*, the *Danube*, the *Neiſter* the *Boryſtenes*, the *Tanais*, and the *Nile*. Each of theſe he ſuppoſes to bring down ten Times as much Water as the *Thames*; whereby he allows for ſmaller Rivers, which fall into the ſame Sea. The *Thames* then he finds by Menſuration to diſcharge about 20,300,000 Tons of Water a Day. If therefore the aboveſaid nine Rivers yield ten Times as much Water as the *Thames* doth, it will follow, that all of them together yield but 1827 Millions of Tons in a Day; which is but little more than one Third of what is proved to be raiſed in Vapour out of the *Mediterranean* in the ſame Time. We have therefore from hence a Source abundantly ſufficient for the Supply of Fountains.

Now having found, that the Vapour exhaled from the Sea, is a ſufficient Supply for the Foun-

Fountains; he proceeds in the next Place to conſider the Manner in which they are raiſed; and how they are condenſed into Water again; and conveyed to the Sources of Springs.

In Order to this he conſiders, that, if an Atom of Water was expanded into a Shell or Bubble, ſo as to be ten Times as big in Diameter as when it was Water, that Atom would become ſpecifically lighter than Air; and therefore would riſe ſo long as the Warmth which firſt ſeparated it from the Surface of the Water ſhould continue to diſtend it to the ſame Degree; and conſequently, that Vapours may be raiſed from the Surface of the Sea in that Manner, till they arrive at a certain Height in the Atmoſphere, at which they find the Air of equal ſpecific Gravity with themſelves. Here they will float, till being condenſed by Cold, they become ſpecifically heavier than the Air, and fall down in Dew, or being driven by the Winds againſt the Sides of the Mountains, (many of which far ſurpaſs the uſual Height to which the Vapours would of themſelves aſcend) are compelled by the Stream of the Air to mount up with it to the Tops of them: where being condenſed into Water they preſently precipitate, and gleeting down by the Crannies of the Stone, Part of them enters into the Caverns of the Hills; which being once filled, all the over-

plus

plus of Water that comes thither, runs over by the loweſt Place, and breaking out by the Sides of the Hills, forms ſingle Springs. Many of theſe running down by the Valleys between the Ridges of the Hills, and coming to unite, form little Rivulets or Brooks: Many of theſe again meeting in one common Valley, and gaining the plain Ground, being grown leſs rapid, become a River; and many of theſe being united in one common Channel, make ſuch Streams as the *Rhine* and the *Danube*; which latter, he obſerves, one would hardly think to be a Collection of Water condenſed out of Vapour, unleſs we conſider how vaſt a Tract of Ground that River drains, and that it is the Sum of all thoſe Springs, which break out on the South Side of the *Carpathian* Mountains, and on the North Side of the immenſe Ridge of the *Alps*; which is one continued Chain of Mountains from *Switzerland* to the *Black-Sea*.

Thus one Part of the Vapours, which are blown on the Land, is returned by the Rivers into the Sea, from whence it came; another Part falls into the Sea before it reaches the Land; and this is the Reaſon, why the Rivers do not return ſo much Water into the *Mediterranean* as is raiſed in Vapour. A third Part falls on the Low-Lands, and is the *Pabulum* of Plants, where yet it does not reſt; but is again exhaled by Vapour by the Action

Action of the Sun, and is either carried by the Winds to the Sea, to fall in Rain or Dew there, or elſe to the Mountains to become the Sources of Springs.

However, it is not to be ſuppoſed, that all Fountains are owing to one and the ſame Cauſe; but that ſome proceed from Rain and melted Snow, which ſubſiding through the Surface of the Earth, makes its Way into certain Cavities and thence iſſues out in the Form of Springs; becauſe the Waters of ſeveral are found to increaſe and diminiſh in Proportion to the Rain which falls: That others again, eſpecially ſuch as are ſalt, and ſpring near the Sea-Shore, owe their Origin to Sea-Water percolated through the Earth; and ſome to both theſe Cauſes: Though without doubt moſt of them, and eſpecially ſuch as ſpring near the Tops of high Mountains, receive their Waters from Vapours, as before explained *.

* There is a certain Species of Springs which ebb and flow alternately, and ſome that ceaſe to flow for a Time, which from thence are called reciprocating or intermitting ones. Their Reciprocations may be accounted for in the following Manner.

Let ABC repreſent one Side of an Hill in which there is a Cavity DEF, and from this a ſubterraneous Duct IKL. Now as this Cavity fills with Water (ſuppoſe from Vapours percolating through the Surface of the Hill, or in any other Manner whatever) its Surface will riſe in the Duct as it does in the Cavity, till it arrives at M, the Level with the upper Part of the Duct; at which Time it will run over at K, filling KLA the other Part of the Duct. Now, if the Column KL is longer than KI it will overpoiſe the other, and ſo cauſe the Water to run out at A, till its Surface in the Cavity ſinks as far as I, (provided the Duct is large enough to convey the Water away faſter than

than it enters the Cavity) at which Time the Fountain at A will ceaſe to play, till the Surface of the Water in the Cavity riſes again to M, and runs over at K as before. The Reaſon why the Water continues running (when the Duct is once full) till its Surface ſinks to I, is becauſe the Air preſſing againſt it as it runs out at A and alſo upon its Surface in the Cavity, keeps the Duct full, as long as the Water in the Cavity is high enough to feed its Orifice at I.

See more on this Subject in Philoſoph. Tranſact. No. 119, 189, 192, 384, 424. Hiſtory de l' Acad. 1693, 1703, 1713. *Gulielmini* della Natura de Fiumi. *Dale*'s Hiſtory of *Harwich*. *Marriotte*'s Hydroſtatics. *Nieuwentyt* Contempt. 19. *Varenius* Geograph. Cap. 16. *Regnault* Vol. 2. Converſat. 6. *Hales*'s Statical Eſſays Vol. 1. Experiment 19. *Michelottus* in Append ad *J. Bernoullii* de Effervesc.

Fig. 17. P. 60.

Fig. 18. P. 63.

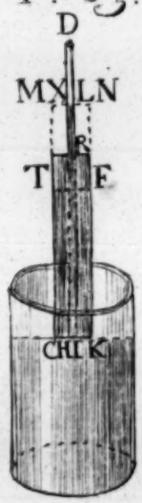


Fig. 19. P. 64.

Fig. 20. P. 66.

Fig. 21. P. 67.

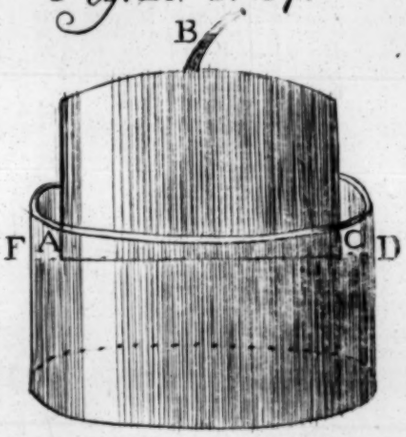


Fig. 22. P. 67.

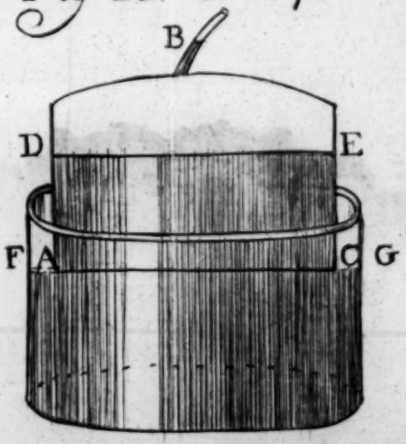


Fig. 23. P. 68.

Fig. 24.

Fig. 25. P. 71.

Fig. 26

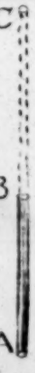
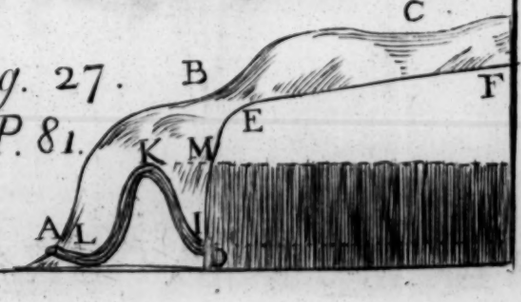


Fig. 27. P. 81.




BIBLIOTHECA · BODLEIANA

A

COMPENDIOUS SYSTEM OF Natural Philoſophy.

With NOTES,

Containing the MATHEMATICAL DEMONSTRATIONS, and ſome occaſional REMARKS.

PART II. Continued.

Conſiſting of five *DISSERTATIONS.*

I. Of the *Barometer.*
II. Of the Cauſe and Origin of the *Winds.*
III. Of the Aſcent of *Vapours*, and their Reſolution into *Rain*, *Hail*, *Snow*, &c.
IV. Of the Cauſes of *Thunder* and *Lightning*, with a Solution of the *Phænomena* of the *Aurora Borealis.*
V. A New Theory of *Fermentation.*

By *J. ROWNING*, M. A.
Rector of ANDERBY in LINCOLNSHIRE, and late Fellow of MAGDALEN College in CAMBRIDGE.

The SECOND EDITION.

LONDON:
Printed for SAM. HARDING, Bookſeller, on the Pavement in St. *Martin's Lane.*
MDCCXXXVIII.


BIBLIOTHECA BODLEIANA

DISSERTATION IV.

Of the Barometer.

IN treating of the Properties of the Air (Chap. III.) I have already taken Notice of the Conſtruction of the common Barometer; and proved, that the Aſcent and Suſpenſion of the Mercury therein, is owing to the Preſſure * of the Air. I proceed now to a more particular Inquiry into the Original, and Uſe of this Inſtrument; and the different Forms under which it has appeared, ſince the Time of its Inventor *Torricelli*.

In

* To ſay the Aſcent and Suſpenſion of the Mercury is owing to the Preſſure and Elaſticity of the Air, as is commonly done, is inaccurate. The Variation, indeed, in the Height of the Mercury, may be aſcribed to the Elaſticity of the Air, but no otherwiſe, than as to its *remote* Cauſe; *viz.* as it occaſions an Alteration in the Quantity of Air, impending over the Place where the Variation happens; which alters its Weight, and ſo the Mercury is proportionably raiſed or depreſſed. To illuſtrate this, let it be ſuppoſed, that the Air is every where in *Æquilibrio*, quite round the Globe, and at perfect Reſt; and then, that its Elaſticity, in ſome one Place near the Surface of the Earth, is augmented by the Heat of the Sun, all the reſt of it remaining as before. The Conſequence of this will be, that the ſuperior Part of the Atmoſphere, over this Place, will be raiſed higher by the Expanſion of the inferior Air; and therefore, being unconfined, will ſpread itſelf, every way, over the neighbouring Columns, which we ſuppoſe to retain their former State. The Quantity of Matter therefore in thoſe Columns of Air, in whoſe lower Parts its Elaſticity was increaſed, will be diminiſhed, and that of the neighbouring

In the Beginning of the laſt Century, it was a prevailing Opinion among Philoſophers, that the Univerſe was full of Matter; and that Nature (as they expreſſed it) abhorred a *Vacuum:* Accordingly they imagined, that if a Fluid was ſucked up a Pipe with a ſufficient Force, it would riſe to any Height whatever; ſince Nature would not ſuffer any Part of the Pipe to remain empty. *Galilæo*, who flouriſhed about that Time, found upon Trial, that the common Pump would not raiſe Water, unleſs the Sucker reached within three and thirty Feet of its Surface in the Well *: From hence

ones augmented. A Barometer therefore placed in thoſe Regions, where the Air was rarified, will ſubſide; while one in the neighbouring Countries will aſcend; and they will continue at different Heights, till the denſer Air, ruſhing in upon the rarified, reſtores the *Æquilibrium.* Thus, we ſee, the Variation of the Air's Elaſticity is not the *immediate* Cauſe of the Variation in the Barometer; it firſt affects the Weight of the Air, by altering the Quantity incumbent over any Place, and that affects the Barometer. But, if we may have Recourſe to *remote* Cauſes, we may, if we pleaſe, go one Step farther; and ſay, the Aſcent and Suſpenſion of the Mercury is owing to the Heat of the Sun; for by the foregoing Inſtance, a Variation in the Heat of the Sun may ſometimes be the occaſion of a Variation in the Height of the Mercury.

Neither is the Suſpenſion of the Mercury, in a Tube, that is kept within Doors, to be aſcribed to the Elaſticity of the Air; for that exerts no Force, but as the internal Air is preſſed by the external, which endeavours to get in, where-ever it can find a Way.

* It is a common Notion, that a ſucking Pump will not raiſe Water above thirty-three Feet, whereas it will raiſe it to any Height whatever, if the Sucker reaches within thirty-three Feet of the Surface of the Water; as will be evident to any one that conſiders the Structure of the Pump: For all the Water, which has once

hence he judiciouſly inferred, that a Column of Water thirty-three Feet high was a Counterpoiſe to a Column of Air of an equal Baſe, whoſe Height extended to the Top of the Atmoſphere; and that, for this Reaſon, the Water would not follow the Sucker any farther. *Torricelli*, obſerving this, took the Hint; and conſidered, that, if a Column of Water, of about thirty-three Feet, was equal in Weight to a Column of Air, of the ſame Baſe *; a Co-

once paſſed through the Valve in the Sucker, is ſupported by that, as the Sucker is drawn up, and reſts upon a Valve placed in the Pump below, as it is let down; ſo that it can be no Impediment to the riſing of the Water below the Sucker, whatever the Length of the Column, which it forms, may be. The placing one Pump above another, where Water is to be raiſed from great Depths, is rather for Strength and Conveniency, than out of Neceſſity.

* Perhaps it may be enquired here, how it comes to paſs, that the Column of Air, which preſſes upon the ſtagnant Mercury in the Baſon, is always ſuppoſed to have an equal Baſe with the ſuſpended Column in the Tube; whereas, in Reality, its Baſe is equal to the Surface of the ſtagnant Mercury. The Reaſon is, that, as the Baſe of the Column of Air increaſes, in the ſame Proportion the Velocity, wherewith it deſcends, decreaſes, when it forces down the Surface of the Mercury in the Baſon; conſequently its Moment, or Preſſure upon the Surface of the ſtagnant Mercury (ſo far as it relates to the ſuſpending of it in the Tube) is no greater, than it would have been, had its Baſe been equal to that of the ſuſpended Column; and therefore, in conſidering it as ſuſpending a Fluid in a Tube, it is properly enough ſaid to be a Column of ſuch a Baſe.

Neither is this Suppoſition inconſiſtent with the ninth Propoſition of the firſt Chapter, where it is demonſtrated, that the Preſſure of a Fluid is in Proportion to its perpendicular Height, and the Quantity of Surface, againſt which it preſſes. For, as the Surface of the Mercury may be conſidered as a Baſe on which the

Column of Mercury, no longer than about twenty-nine Inches and a half, would be ſo too; ſuch a Column of Mercury being as heavy, as thirty-three Feet of Water. Accordingly he tried the Experiment in a Glaſs Tube (in the Manner laid down, Chap. III. §. 4.) and found it to ſucceed *. The Apparatus he made Uſe of,

Column of Air reſts, ſo the Baſe of the Column of Air may be conſider'd as a Surface againſt which the Mercury preſſes. Theſe two being equal, 'tis clear, that only the Relation of the Heights of the Columns are to be conſidered, and not that of their Baſes.

* Notwithſtanding this clear Proof of the Preſſure of the Atmoſphere, the Aſſerters of a *Plenum* would by no Means be prevailed upon to allow it to be ſuch; but tried all Ways to account for this *Phænomenon* from ſome other Cauſe. The moſt chimerical Solution, and which at the ſame Time gave the adverſe Party the greateſt Difficulty to overthrow, was that of *Linus*. He contended, that in the upper Part of the Tube, there is a Film, or Rope of Mercury, extended thro' the ſeeming Vacuity, and that the reſt was ſuſpended by it, and kept from falling into the Baſon; and that this Film is able to ſupport about twenty-nine Inches of Mercury. He confirms his *Hypotheſis* by the following Experiment. Take, ſays he, a ſmall Tube, open at both Ends, ſuppoſe about twenty Inches long; fill this Tube with Mercury, ſtopping the lower Orifice with your Thumb: Then cloſing the upper with your Finger, and immerging the lower in ſtagnant Mercury, you ſhall perceive, upon the Removal of your Thumb, a manifeſt Suction of your Finger into the Tube; and the Tube and Mercury will both ſtick ſo cloſe to it, that you may carry them about the Room. Therefore, ſays he, the internal Cylinder of Mercury in the Tube is not held up by the preponderant Air without; for if ſo, whence comes ſo ſtrong a Suction, and ſo firm an Adheſion of the Tube to your Finger?

Or if you fill the ſame Tube almoſt full of Mercury, leaving a little Space of Air within, and then immerge it in the ſtagnant Mercury, you will find, that, notwithſtanding its Surface is at ſome Diſtance from your Finger, there will be a conſiderable Suction,

of, is now the common Barometer or Weather Glaſs *.

The Mercury ſtanding at a leſs Height, the nearer it is carried to the Top of the Atmoſphere,

tion of it, as before. From hence he infers, that the Finger ſupports the Mercury, by Means of the abovementioned Film, and that the Preſſure of the Atmoſphere is not concerned.

But, when it was found, that the Mercury would not ſtand ſo high in the Tube, on the Top of a Mountain, as below; and would quite fall, when the circumambient Air was extracted from it by the Pump, all Objections vaniſhed; and *Linus*'s funicular *Hypotheſis* (as it was called) though it ſeemed to ſolve all other *Phænomena*, relating to the Suſpenſion of the Mercury, was with Juſtice rejected.

Kircher, when this new Doctrine of a *Vacuum* was firſt advanced at *Rome*, contended, that the Authors of it were eſtabliſhing Principles not only repugnant to thoſe of Nature, but ſuch as would be prejudicial to the Orthodox Faith; as endeavouring to evince by this ſubtle Experiment, that there might be in Nature *locatum ſine loco*, *accidentia ſine ſubjecto*, and therefore made the Experiment with Water, in the following Manner. He cauſed a ſmall Bell to be fixed in the upper Part of the Tube, imagining, that, if there ſhould be a *Vacuum*, the Bell would not be made to ſound: But in making the Experiment, ſome Air got into the Tube (for he tells us, that but ten Feet of Water remained in the Tube, after it was inverted) the Bell therefore was heard to ſound; and ſo the Notion of a *Vacuum*, till more accurate Experiments evinced the contrary, was exploded with Contempt.

* *Huygens* obſerved, that, if a Tube ſeventy-five Inches long, was filled with Mercury well purged of its Air, the whole Quantity of Mercury would remain ſuſpended; whereas, according to the *Torricellian* Experiment, the Mercury ought to have ſubſided to the Height of about twenty-nine Inches.

The Cauſe of this *Phænomenon* ſeems to be, that, by the great Weight of ſo long a Column of Mercury, it was preſſed into ſo cloſe Contact with the Glaſs in pouring in, that by the mutual Attraction of Coheſion between the Mercury and the Glaſs, the whole Column was ſuſtained, after the Tube was inverted.

(Chap.

(Chap. III. §. 7.) renders it uſeful in determining the Height of Mountains; and finding out the different Elevation of one Place above another. Accordingly, Dr. *Halley* has given us a Table for that Purpoſe, in the Philoſophical Tranſactions N°. 181, ſhewing how many Feet the Deſcent of the Mercury each Inch anſwers to, as it is conveyed to the Top of a Mountain, or other elevated Place. And Dr. *Nettleton* has done the like in the Philoſophical Tranſactions N°. 388, ſhewing what Number of Feet anſwers to each tenth Part of an Inch, from twenty-ſix to thirty-one Inches of Mercury.

But the principal Uſe of it is, to eſtimate the Gravity of the Air at different Times, in Order to foreſee the Alterations of the Weather, which are conſequent thereon. To this End, Dr. *Halley* in the ſame Tranſaction has alſo laid down the more remarkable *Phænomena*, relating to the different Heights of the Mercury at different Times, together with the Solution of each; which are ſo juſt, and ſo agreeable to true Philoſophy, that I doubt not but the Reader will excuſe me for giving his Account in his own Words, rather than to render it imperfect, by endeavouring to vary from it, or abridge it.

" 1. In calm Weather, when the Air is in-
" clined to Rain, the Mercury is commonly
" low.

" In

" 2. In ſerene, good, ſettled Weather, the " Mercury is generally high.

" 3. Upon very great Winds, though they " be not accompanied with Rain, the Mercury " ſinks loweſt of all, with Relation to the " Point of the Compaſs the Wind blows upon.

" 4. *Cæteris paribus*, the greateſt Heights " of the Mercury are found upon eaſterly and " north-eaſterly Winds.

" 5. In calm froſty Weather, the Mercury " generally ſtands high.

" 6. After very great Storms of Wind, " when the Mercury has been low, it gene- " rally riſes again very faſt.

" 7. The more northerly Places have greater " Alterations of the Barometer, than the more " ſoutherly.

" 8. Within the Tropics, and near them, " thoſe Accounts we have had from others, " and my own Obſervations at St. *Helena*, " make very little or no Variation of the " Height of the Mercury in all Weathers.

" Hence I conceive that the principal Cauſe " of the Riſe and Fall of the Mercury, is from " the variable Winds, which are found in the " temperate Zone, and whoſe great Uncon- " ſtancy, here in *England*, is moſt notorious.

" A ſecond Cauſe is the uncertain Exhalation " and Precipitation of the Vapours lodging in " the Air, whereby it comes to be at one Time, " much more crouded than at another, and

" con-

" conſequently heavier, but this latter in a great " Meaſure depends upon the former. Now, " from theſe Principles, I ſhall endeavour to " explicate the ſeveral *Phænomena* of the Ba- " rometer, taking them in the ſame Order I " laid them down. Thus.

" 1. The Mercury's being low, inclines it " to rain, becauſe the Air being light, the " Vapours are no longer ſupported thereby, " being become ſpecifically heavier than the " Medium wherein they floated, ſo that they " deſcend towards the Earth, and in their Fall, " meeting with other aqueous Particles, they " incorporate together, and form little Drops " of Rain; but the Mercury's being at one " Time lower than at another, is the Effect of " two contrary Winds blowing from the Place " where the Barometer ſtands; whereby the " Air of that Place is carry'd both Ways from " it, and, conſequently, the incumbent Cylin- " der of Air is diminiſhed, and accordingly the " Mercury ſinks: As for Inſtance, if in the " *German* Ocean it ſhould blow a Gale of " weſterly Wind, and at the ſame Time an " eaſterly Wind in the *Iriſh* Sea; or if in " *France* it ſhould blow a northerly Wind, " and in *Scotland* a ſoutherly; it muſt be " granted, that that Part of the Atmoſphere " impendant over *England*, would thereby be " exhauſted and attenuated, and the Mercury " would ſubſide, and the Vapours, which be-

" fore

" fore floated in thoſe Parts of the Air of
" equal Gravity with themſelves, would ſink
" to the Earth.

" 2. The greater Height of the Barometer
" is occaſioned by two contrary Winds blow-
" ing towards the Place of Obſervation, where-
" by the Air of other Places is brought thither
" and accumulated; ſo that the incumbent
" Cylinder of Air, being encreaſed both in
" Height and Weight, the Mercury preſſed
" thereby muſt needs ſtand high, as long as
" the Winds continue ſo to blow; and then
" the Air being ſpecifically heavier, the Va-
" pours are better kept ſuſpended, ſo that they
" have no Inclination to precipitate and fall
" down in Drops, which is the Reaſon of the
" ſerene good Weather which attends the
" greater Heights of the Mercury.

" 3. The Mercury ſinks the loweſt of all by
" the very rapid Motion of the Air in Storms
" of Wind. For the Tract or Region of the
" Earth's Surface, wherein the Winds rage,
" not extending all round the Globe, that
" ſtagnant Air which is left behind, as like-
" wiſe that on the Sides, cannot come in ſo
" faſt as to ſupply the Evacuation made by ſo
" ſwift a Current, ſo that the Air muſt neceſ-
" ſarily be attenuated, when and where the
" ſaid Winds continue to blow, and that more
" or leſs, according to their Violence; add
" to which, that the horizontal Motion of the

" Air being ſo quick as it is, may, in all Pro-
" bability, take off ſome Part of the perpendi-
" cular Preſſure thereof; and the great Agi-
" tation of its Particles is the Reaſon why the
" Vapours are diſſipated, and do not condenſe
" into Drops, ſo as to form Rain, otherwiſe
" the natural Conſequence of the Air's Rare-
" faction †.

" 4. The Mercury ſtands the higheſt upon
" the eaſterly and north-eaſterly Wind, be-
" cauſe in the great *Atlantic* Ocean, on this
" Side the thirty-fifth Degree of north Lati-
" tude, the Winds are almoſt always weſter-
" ly or ſouth-weſterly; ſo that whenever
" here the Winds come up at eaſt and north-
" eaſt, 'tis ſure to be checked by a contrary
" Gale as ſoon as it reaches the Ocean; where-
" fore, according to what is made out in our
" ſecond Remark, the Air muſt needs be heap-

† The Reaſon the Doctor aſſigns for the ſinking of the Mercury the loweſt of all in violent Storms of Wind, ſeems not ſufficient. Perhaps it may be better accounted for thus: the Cauſe why the Wind blows at all, is in order to reſtore the *Æquilibrium* of the Atmoſphere, when loſt (as may be inferred from what was ſaid in the firſt Note of this, and will be more largely explained in the following Diſſertation,) it therefore always blows towards that Point, where the Air is moſt rarefied and lighteſt. Now the Air in its Progreſs to that Point, muſt certainly move faſter and faſter; for the Cauſe which gave it Motion at firſt, continues to act upon it all the Way. Conſequently, in whatever Place the Wind blows with great Rapidity, that Place is at, or near the Point, where the Air is moſt rarefied, and lighteſt; which is a ſufficient Reaſon for the Mercury's ſtanding low at that Place.

" ed

" ed over this Iſland, and conſequently the " Mercury muſt ſtand high, as often as theſe " Winds blow. This holds true in this Coun- " try, but is not a general Rule for others, " where the Winds are under different Cir- " cumſtances; and I have ſometimes ſeen the " Mercury here, as low as twenty-nine Inches " upon an eaſterly Wind, but then it blew ex- " ceeding hard, and ſo comes to be accounted " for, by what was obſerved upon the third " Remark.

" 5. In calm froſty Weather the Mercury " generally ſtands high, becauſe (as I con- " ceive) it ſeldom freezes, but when the Winds " come out of the northern, and north-eaſtern " Quarters; or, at leaſt, unleſs thoſe Winds " blow at no great Diſtance off: For the " north Parts of *Germany*, *Denmark*, *Swe- " den*, *Norway*, and all that Tract from " whence north-eaſtern Winds come, are " ſubject to almoſt continual Froſt all the " Winter; and thereby the lower Air is very " much condenſed, and in that State is brought " thitherwards by thoſe Winds, and being ac- " cumulated by the Oppoſition of the weſter- " ly Wind blowing in the *Ocean*, the Mer- " cury muſt needs be preſſed to a more than " ordinary Height: and, as a concurring " Cauſe, the ſhrinking of the lower Parts of " the Air into leſſer Room by Cold, muſt

" needs cauſe a Deſcent of the upper Parts of " the Atmoſphere, to reduce the Cavity made " by this Contraction to an *Æquilibrium*.

" 6. After great Storms, when the Mer- " cury has been very low, it generally riſes " again very faſt: I once obſerved it to riſe " one Inch and a half in leſs than ſix Hours, " after a long continued Storm of ſouth-weſt " Wind. The Reaſon is, becauſe the Air be- " ing very much rarefied, by the great Eva- " cuations which ſuch continued Storms make " thereof, the neighbouring Air runs in the " more ſwiftly, to bring it to an *Æquilibri-* " *um*; as we ſee Water runs the faſter for " having a greater Declivity.

" 7. The Variations are greater in the more " northerly Places, as at *Stockholm*, greater " than that at *Paris* (compar'd by M. *Paſ-* " *chal*;) becauſe the more northerly Parts " have uſually greater Storms of Wind than " the more ſoutherly, whereby the Mercury " ſhould ſink lower in that Extream; and " then the northerly Winds bringing the more " denſe and ponderous Air from the Neigh- " bourhood of the Pole, and that again being " checked by a ſoutherly Wind at no great " Diſtance, and ſo heaped, muſt of Neceſſity " make the Mercury in ſuch Caſe ſtand higher " in the other Extream.

" 8. Laſtly,

" 8. Laſtly, this Remark, That there is " little or no Variation near the *Equinoctial*, " does above all others confirm the *Hypothe-* " *ſis* of the variable Winds being the Cauſe of " theſe Variations of the Height of the Mer- " cury; for in the Places above-named, there " is always an eaſy Gale of Wind blowing " nearly upon the ſame Point, *viz.* eaſt-north- " eaſt, at *Barbadoes*, and eaſt-ſouth-eaſt at " St *Helena* *, ſo that there being no contra- " ry Currents of Air to exhauſt or accumulate " it, the Atmoſphere continues much in the " ſame State: However, upon Hurricanes " (the moſt violent of Storms) the Mercury " has been obſerved very low, but this is but " once in two or three Years, and it ſoon re- " covers its ſettled State about 29 ½ Inches."

Monſieur *Leibnitz* accounted for the Deſcent of the Mercury before Rain, upon another Principle †, *viz.* as a Body ſpecifically lighter than a Fluid, while it is ſuſpended by it, adds more Weight to that Fluid, than when, by being reduced in its Bulk, it becomes ſpecifically heavier, and deſcends; ſo the Vapour, after it is reduced into the Form of Clouds, and deſcends, adds leſs Weight to the Air, than before; and therefore the Mer-

* See the Cauſe of this aſſigned in the following Diſſertation.

† Memoir. de l'Acad. 1711.

cury

cury falls. To which it is anſwered, 1*ſt*. That when a Body deſcends in a Fluid, its Motion, in a very little Time, becomes uniform, (or nearly ſo) a farther Acceleration of it being prevented by the Reſiſtance of the Fluid; and then, by the third Law of Nature, it preſſes the Fluid downwards, with a Force equal to that whereby it tends to be farther accelerated, that is, with a Force equal to its whole Weight. 2*dly*. The Mercury, by its Deſcent, foretells Rain a much longer Time before it comes, than the Vapour, after it is condenſed into Clouds, can be ſuppoſed to take up in falling. 3*dly*. Suppoſing that as many Vapours, as fall in Rain, during the Space of a whole Year, were at once to be condenſed into Clouds, and even quite ceaſe to gravitate upon the Air, its Gravity would ſcarce be diminiſhed thereby, ſo much as is equivalent to the Deſcent of two Inches of Mercury in the Barometer. Farther, in many Places between the Tropics, the Rains fall at certain Seaſons, in very great Quantities *, and yet the Barometer ſhews there very little or no Alteration in the Weight of the Air.

The following are Mr. *Patrick*'s Obſervations on the riſing and falling of the Mercury. They are very juſt, and are to be accounted

* See Diſſertation the vith.

for

for on the ſame Principles with thoſe of Dr. *Halley*.

" 1. The riſing of the Mercury preſages in " general fair Weather; and its falling, foul " Weather; as Rain, Snow, high Winds and " Storms.

" 2. In very hot Weather, the falling of " the Mercury foreſhews Thunder.

" 3. In Winter the riſing preſages Froſt; " and in froſty Weather, if the Mercury falls " three or four Diviſions, there will *certain-* " *ly* follow a Thaw. But in a continued " Froſt, if the Mercury riſes, it will *certain-* " *ly* ſnow.

" 4. When foul Weather happens ſoon after " the Falling of the Mercury, expect but little " of it. And, on the contrary, expect but " little fair Weather, when it proves fair " ſhortly after the Mercury has riſen.

" 5. In foul Weather, when the Mercury " riſes much and high, and ſo continues for " two or three Days before the foul Weather " is quite over, then expect a Continuance of " fair Weather to follow.

" 6. In fair Weather, when the Mercury " falls much and low, and thus continues for " two or three Days before the Rain comes; " then expect a great deal of wet, and pro- " bably high Winds.

" 7. The

" 7. The unſettled Motion of the Mercury " denotes uncertain and changeable Weather.

" 8. You are not ſo ſtrictly to obſerve the " Words engraven on the Plates (though, for " the moſt Part, it will agree with them) as " the Mercury's *Riſing* and *Falling:* For if " it ſtands at *Much Rain*, and then riſes up " to *Changeable*, it preſages fair Weather, al- " though not to continue ſo long, as it would " have done, if the Mercury were higher: " And ſo on the contrary, if the Mercury " ſtood at *Fair*, and falls to *Changeable*, it " preſages foul Weather; though not ſo much " of it, as if it had ſunk down lower."

From theſe Obſervations, it appears, That it is not ſo much the Height of the Mercury in the Tube, that indicates the Weather, as the Motion of it up and down; wherefore, in Order to paſs a right Judgment of what Weather is to be expected, we ought to know, whether the Mercury is actually *Riſing* or *Falling*, to which End, the following Rules are of Uſe.

1. If the Surface of the Mercury is convex, ſtanding higher in the Middle of the Tube than at the Sides, it is generally a Sign that the Mercury is then riſing.

2. If the Surface is concave, or hollow in the Middle, it is ſinking. And,

3. If

3. If it is plain, the Mercury is ſtationary, or rather, if it is a little convex; for Mercury being put into a Glaſs Tube, eſpecially a ſmall one, will naturally have its Surface a little convex; becauſe the Particles of Mercury attract each other more forcibly than they are attracted by Glaſs. Further,

4. If the Glaſs is ſmall, ſhake the Tube; and if the Air is growing heavier, the Mercury will riſe about half the tenth of an Inch higher, than it ſtood before; if it is growing lighter, it will ſink as much. This proceeds from the Mercury's ſticking to the Sides of the Tube, which prevents the free Motion of it, till it is diſengaged by the Shock. And therefore, when an Obſervation is to be made with ſuch a Tube, it ought always to be ſhaken firſt, for ſometimes the Mercury will not vary of its own Accord, till the Weather, it ought to have indicated, is preſent.

The Uſefulneſs of knowing, whether the Mercury is actually riſing or falling; and the Advantage that would ariſe from perceiving the moſt minute Variations in eſtimating the Heights of Places, have given Occaſion to the Invention of ſeveral Kinds of Barometers different from the *Torricellian*, though founded on the ſame Principle; wherein the Scale of Variation, which in that is not above three Inches,

ſhould be conſiderably larger. Of which I am now to give ſome Account.

1. The firſt is that of *Des Cartes*, which was made in the Form expreſſed *Fig.* 28. where AB is a Tube hermetically * ſealed at A, and having its lower Orifice immerged in ſtagnant Mercury EF, and filled with the ſame Fluid to G, from thence to H with Water, and empty from thence to the Top. Now, when the Mercury riſes in this Tube, ſuppoſe from G to L, the Water will be raiſed in the ſmall Tube, perhaps from H to M, *viz.* as many Times further, as the Tube CA is ſmaller than CD; by which Means the Variations become much more ſenſible, than they are in the common Barometer. The Inconvenience of this was, that the Air, included in the Water, getting looſe by Degrees, filled the void Space at the Top, and ſo ſpoiled the Machine.

2. He then contrived it thus, ABC (*Fig.* 29.) is a bent Tube hermetically ſealed at A, filled with Water from F to D (tinged with *Aqua Regia* to prevent its freezing,) from D to E with Mercury, and empty from thence to the Top. Then, upon the Mercury's riſing, ſuppoſe from

* A Tube is ſaid to be *hermetically* ſealed, when the End is ſo cloſed, that nothing can poſſibly evaporate through it. And, becauſe this is beſt done, when it is cloſed up with its own Subſtance; or when its Bore does not reach quite through it, it is then ſaid to be *hermetically* ſealed.

E to

E to M, and falling as much at D, the Surface of the Water at F would ſink ſo many Times farther than the Surface of the Mercury at D, as the Tube CG was ſmaller than GH. The Water here is liable to evaporate, though that may, in ſome Meaſure, be prevented, by pouring a few Drops of Oil of ſweet Almonds upon it. Others have contrived

3. The Horizontal or Rectangular Barometer (*Fig.* 30.) hermetically ſealed at A, and filled with Mercury from D to E; then as the upper Surface of it riſes in the Tube, ſuppoſe from E to F, the lower will be driven from D to G, as many Times farther, as this Part of the Tube is leſs than that at E. But it often happens, that ſome Parts of the Mercury break off from the reſt in the Leg BC, and are left behind. This Inconvenience is remedied in

4. The Diagonal Barometer ABC (*Fig.* 31.) wherein the Mercury, inſtead of riſing from B to D (ſuppoſe that Space to correſpond to the Scale of Variation in a ſtrait Tube) will riſe from B to A; for it will always ſtand at the ſame perpendicular Height, whatever be the Inclination of the Tube; becauſe Fluids preſs only according to their perpendicular Altitude *. But the Tube AB muſt not be too much inclined, leſt the Mercury break in it, as in the former.

* Chapter I. §. 9.

5. AB (*Fig.* 32.) is Dr. *Rook*'s Wheel-Barometer, wherein ABD is a Tube filled with Mercury from *a* to E; *a* is an Iron Ball, ſwimming on the Surface of the Mercury; this as it ſubſides with the Surface of the Mercury, draws the little Wheel *m n* round, to whoſe Circumference it is fixed by Means of the String *a c* *: This Wheel carries the Index PQ, which points to the graduated Edge of the Circle KL, and by its Motion ſhews the moſt minute Variations of the Mercury. When the Ball *a* is raiſed by the Mercury on which it ſwims, the Index is drawn the contrary Way by a leſſer Ball *b*, which hangs on the other Side the Wheel. The Friction in this Machine, unleſs it be made with great Accuracy indeed, renders it uſeleſs.

6. The pendent Barometer is another Contrivance to render the Variations more ſenſible. It conſiſts of a ſmall conical Tube, (repreſented *Fig.* 33.) hermetically ſealed at A, and filled with Mercury from C to D, and empty from thence to A. Now, ſuppoſing the Gravity of the Air encreaſed, it will raiſe the Mercury higher in the Tube, and ſo force it into a narrower Part; by which Means the Column becoming longer, its perpendicular Preſſure upon the Air below will be proportionably encreaſed.

* The Tube is ſmaller at *a* than at E, that the greateſt Variation may be at that Surface of the Mercury on which the Ball reſts.

On

On the contrary, when the Air becomes lighter, the Mercury deſcends into a larger Part of the Tube, and by that Means has the Length of its Column proportionably contracted. The Inconvenience that attends this Barometer, is that the Tube muſt be very ſmall, otherwiſe the Mercury will fall out; or the Air will be apt to get into it, and divide the Column in ſeveral Places; and when the Tube is very ſmall, the Friction of the Mercury againſt the Sides of it, will hinder it from riſing and falling freely.

7. Dr. *Hook*, obſerving how unfit the common Barometer was to be uſed on Board of Ship, by Reaſon its Poſition ought to be ſteady, contrived the following one, called, from its Uſe, a *Marine* Barometer, conſiſting of two Parts, the one A B (*Fig.* 34.) the common Spirit Thermometer, the other C D, a Tube filled with Air from C to E, and from thence to the End D with tinged Water. This End is immerged in the ſame Fluid contained in the Veſſel G F; and having its Surface expoſed to the Preſſure of the external Air. Now, the laſt of theſe Machines will be affected both by the Warmth of the external Air, and alſo by its Preſſure: The former dilating the Air included in C E, and by that Means driving the Water downwards; the latter preſſing it up higher in the Tube: Whereas the other, *viz.* AB, is affected by the Warmth of the Air alone. Conſequently,

ſequently, were theſe Inſtruments graduated in ſuch a Manner, that, if the Gravity of the external Air ſhould always remain the ſame it was, when the Inſtruments were made, their Variations (then only depending on its Warmth) ſhould exactly correſpond with each other; that is, when the Spirit in the Tube A B, ſhould aſcend to 1, the Water in C D, ſhould deſcend to 1, *&c.* Then, whenever their Variations ſhould be obſerved to differ from each other, the Difference could only be aſcribed to ſome Alteration in the Preſſure of the Air upon the Surface of the Water in the Veſſel G F. In Proportion therefore as this Difference is greater, or leſs, ſo is the Alteration in the Gravity of the Air, from what it was when the Inſtruments were adjuſted. For Inſtance, when the Water ſtands above the Diviſion, which correſponds to that, which the Spirit points to in the other Machine, it is an Indication, that the Preſſure of the Air is greater at that Time, than when the Inſtruments were graduated, and *vice verſâ*.

This Machine is not only more uſeful at Sea, than the common one, as not requiring a ſteady Poſition; but may have its Scale of Variation conſiderably enlarged, by making the Bore of the Tube C D very ſmall, in Proportion to the Capacity of its Head C.

But

But it is obſerved, that in long keeping this Inſtrument, the included Air loſes ſomewhat of its Elaſticity; whereby, in Proceſs of Time, the Water ſtands higher than it ought, and therefore indicates the Gravity of the Air to be greater than what it is.

In the Philoſophical Tranſactions N°. 427. I have given an Account of a Barometer, wherein the Scale of Variation may be encreaſed *ad Infinitum*. The Deſcription of it is as follows: A B C D (*Fig.* 35.) is a cylindrical Veſſel, filled with a Fluid to the Height W, in which is immerged the Barometer S V, conſiſting of the following Parts: The Principal of which is a Glaſs Tube T P (repreſented ſeparately at *t p*) whoſe upper End T is hermetically ſealed: This End does not appear to the Eye, being received into the lower End of a Tin Pipe G H, which in its other End G receives a cylindrical Rod, or Tube ST, and thereby fixes it to the Tube TP. This Rod ST may be taken off, in Order to put in its ſtead a larger, or leſſer, as Occaſion requires. S is a Star at the Top of the Rod ST, and ſerves as an Index, by pointing to the graduated Scale L A, which is fixed to the Cover of the Veſſel A B C D. M N is a large cylindrical Tube made of Tin (repreſented ſeparately at *m n*) which receives in its Cavity the ſmaller Part of the Tube TP, and is well cemented to it at

at both Ends, that none of the Fluid may get in.

The Tube TP, with this Apparatus, being filled with Mercury, and plunged into the Baſon V, which hangs by two, or more Wires, upon the lower End of the Tube MN, muſt be ſo poized, as to float in the Liquor contained in the Veſſel A B C D, and then the whole Machine will riſe, when the Atmoſphere becomes lighter, and *vice verſâ*.

I ſhall here add a Computation, in Order to ſhew the Poſſibility of the Variation being infinite, upon a given finite Variation of the Weight of the Atmoſphere, and withal, the Reaſon why it may be ſo. And for the Sake of thoſe who would ſee a Mathematical Proof of it, I ſhall give the Demonſtration in a Note below. *

Let

* Let the ſpecific Gravity of Quickſilver be to that of Water, or to the Liquor the Barometer floats in, as s to 1; and if it be propoſed, that the Variations in this compound Barometer ſhall be to the contemporary Variations of the common Barometer in the given Ratio of n to 1, this Effect will be obtained, by making the Diameter of the Rod ST to the Diameter of the Cavity of the Tube HI, as $\sqrt{\frac{n+s}{ns}}$ to 1, which may be thus demonſtrated.

Let us ſuppoſe, that the Variation in the Height of the Quickſilver in the common Barometer, which we call v, is ſuch, that a cubic Inch of Quickſilver ſhall riſe into the *Vacuum* XT; in Order to which, a cubic Inch of Quickſilver muſt riſe from the Veſſel V; that is, the Surface P muſt ſubſide ſo far, that a cubic Inch of Water (if that be the Fluid made Uſe of) ſhall enter the Veſſel V, by which Means the Barometer with the Parts annexed will be heavier by a cubic Inch of the Fluid. Now

Fig. 28. Fig. 29. P. 100. Fig. 30 Fig. 31. P. 101.

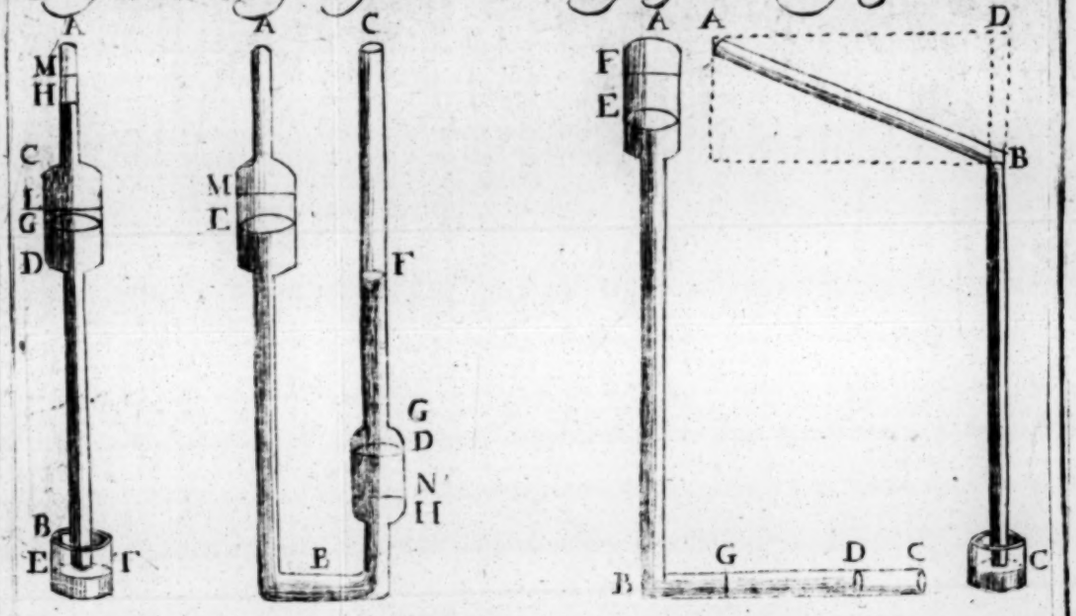
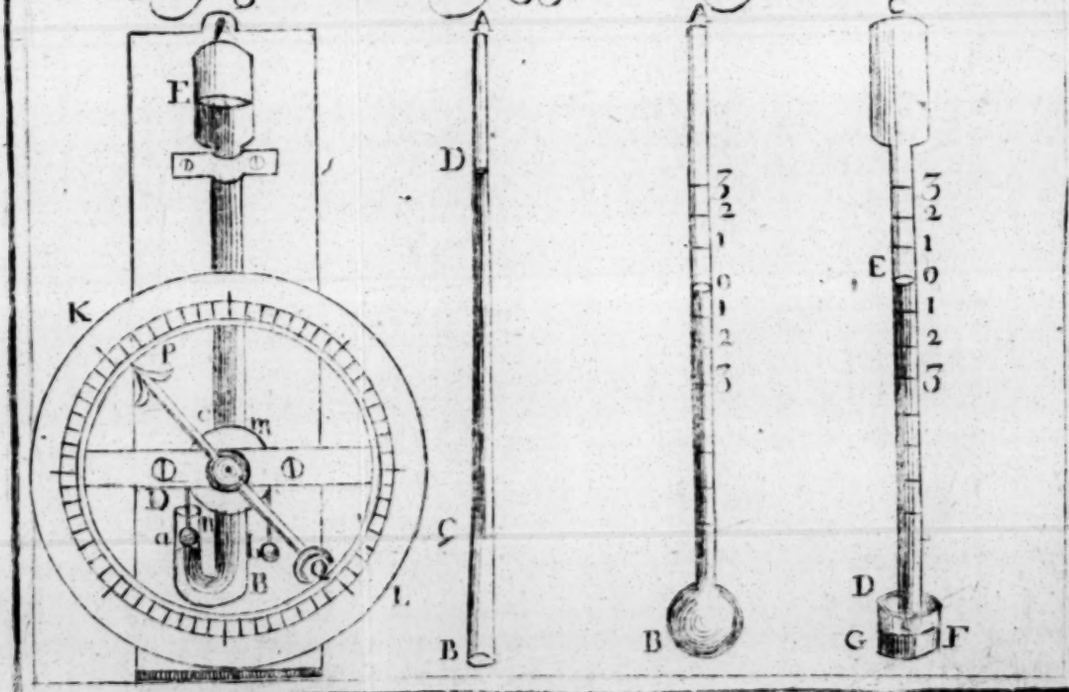


Fig. 32. P. 102. Fig. 33

Fig. 34. P. 103.



BIBLIOTHECA · BODLEIANA

Let it be ſuppoſed, that the Fluid made uſe of is Water, and that the given Variation in the Weight of the Atmoſphere is ſuch, that, by

Now this additional Weight of a cubic Inch of Fluid, will make the whole Barometer ſubſide (according to the Laws of Hydroſtatics) till a cubic Inch of the Rod HS, immediately extant above the Surface at W, ſhall come under it; but the Length of ſuch a Magnitude of HS will exceed the Length of an equal Magnitude of Quickſilver in the larger Tube X, as many Times as the Square of the Diameter at X exceeds the Square of the Diameter at H (the Lengths of equal Cylinders being reciprocal to their Baſes.) That is, the perpendicular Deſcent of the compound Barometer will be to v, the perpendicular Aſcent of the Mercury in the common Barometer, as d to 1 (ſuppoſing this the Ratio of their Baſes, and conſequently will be equal to dv.

But, by this Deſcent, the Diſtance PW, between the Surface of the ſtagnant Quickſilver and the Top of the Fluid, will be augmented by a Column, whoſe Height is dv, the Deſcent of the compound Barometer; and conſequently the Weight of the whole Column of the Fluid preſſing on the lower Surface of the Quickſilver (to which the Height X is partly owing) will be encreaſed by a Column of that Length; and this Increaſe would produce a ſecond Aſcent of the Mercury at X equal to itſelf, namely, dv, were the Fluid as heavy as Quickſilver; but ſince it is ſuppoſed to be lighter in the Ratio of s to 1, the Aſcent of the Quickſilver, on this Account, will only be $\frac{dv}{s}$.

But now, as in the former Caſe, when the Aſcent of the Mercury was v, the Deſcent of the compound Barometer was ſhewn to be dv; ſo here, the Aſcent of the Mercury being $\frac{dv}{s}$ the Deſcent of the common Barometer will be $\frac{ddv}{s}$ and the next Deſcent $\frac{dddv}{ss}$ and the next $\frac{d4v}{s3}$ and ſo on to Infinity. Therefore the whole Deſcent of the compound Barometer, is to the Aſcent of the Mercury in the common Barometer, that is, n is to 1 as $d + \frac{dd}{s} + \frac{ddd}{ss} + \frac{d4}{s3}$ &c. to 1, or as $\frac{ds}{s-d}$ to 1; becauſe the Terms of the Series being in geometrical Proportion, the

by preſſing upon the Surface of it at W, the Surface of the Mercury at X may be raiſed an Inch higher (meaſuring from its Surface at P) than before; and that the Breadth of the Cavity of the Tube at X, and of the Baſon at P are ſuch, that by this Aſcent of the Mercury, there may be a cubic Inch of it in the Cavity X more than before, and conſequently in the Baſon a cubic Inch leſs. Now, upon this Suppoſition, there will be a cubic Inch of Water in the Baſon more than there was before; becauſe the Water will ſucceed the Mercury to fill up its Place. Upon this Account, the whole Machine will be render'd heavier, than it was before, by the Weight of a cubic Inch of Water, and therefore will ſink, according to the Laws of Hydroſtatics (Chap II. §. 5.) till a cubic Inch of that Part of the Rod WS, which

Sum of them all is $\frac{ds}{s-d}$. Hence we have $n=\frac{ds}{s-d}$ and $\frac{n+s}{ns}$: 1; therefore $ns = ds + dn$; that is, $1 : d :: n+s : ns :: \frac{n+s}{ns} : 1$; and therefore, by extracting the ſquare Roots of each Term in the Proportion, $1 : \sqrt{d}$ (that is, the Diameter of ST to the Diameter of HI) as $\sqrt{\frac{n+s}{ns}}$ to 1. *Q. E. D.*

Example 1. Putting $s=14$ and $n=1$, the Variation in each Barometer will be equal, by taking the Diameter of ST to the Diameter of HI, as $\sqrt{\frac{15}{14}}$ to 1, that is, as 30 to 29 nearly.

Example 2. If n be put infinite, the Diameter of ST will be to the Diameter of HI, as $\sqrt{\frac{1}{s}}$ to 1, or 1 to $\sqrt{14}$; that is, as 1 to $3\frac{3}{4}$ nearly.

Was

was above the Surface of the Water at W, comes under it. Then, if we ſuppoſe this Rod ſo ſmall, that a cubic Inch of it ſhall be fourteen Inches in Length, the whole Machine will ſink fourteen Inches lower into the Fluid than before, and conſequently the Surface of the Mercury in the Baſon will be preſſed more than it was before, by a Column of Water fourteen Inches high. But the Preſſure of fourteen Inches of Water is equivalent to one of Mercury (becauſe Water is about fourteen Times lighter than Mercury) this additional Preſſure therefore will make the Mercury aſcend at X, as much as the ſuppoſed Variation in the Weight of the Air did at firſt. This Aſcent will give Room for a ſecond cubic Inch of Water to enter the Baſon; the Machine will therefore be again rendered heavier by the Weight of ſo much Water, and accordingly will ſubſide fourteen Inches farther. This will occaſion another additional Preſſure of Water, which will raiſe another Inch of Mercury, and make the Machine ſink fourteen Inches more, and ſo on, without ever approaching nearer to an *Æquilibrium* with the external Air: and therefore a Scale, anſwering to the Variation of this Barometer, ought ſtrictly and properly to be of an infinite Length; becauſe after this Barometer has ſunk or riſen thouſands of Miles (if that were poſſible) it would ſtill have the ſame Tendency to ſink or riſe on, as when it firſt ſet out.

Now, was the Rod WS ſo ſmall, that a cubic Inch of it ſhould be more than fourteen Inches long (the other Parts remaining as was ſuppoſed above) the Variation in this Barometer would be more than infinite, or negative with Reſpect to thoſe of the common Barometer. The Meaning of which is, that whereas in the common Barometer, the ſuſpended Column of Mercury, by its riſing or falling, approaches nearer to an *Æquilibrium* with the external Air, this Barometer would continually recede from an *Æquilibrium* with it; ſo that the farther it ſhould move up or down, inſtead of acquiring by that Means a leſs Tendency to move on, as the Mercury in the common Barometer does, it would acquire a greater.

On the contrary, when a cubic Inch of the Rod is leſs than fourteen Inches in Length, the Variation will be finite; and may be made to bear any Proportion to thoſe of the common Barometer whatever, as demonſtrated in the foregoing Note.

While I am writing this, another Method occurs to me of making a Barometer, wherein the Scale of Variation ſhall bear any Proportion to that of the common one. It is this; Let there be a compound Tube, as ABC (*Fig.* 36.) hermetically ſealed at A, and open at C, empty from A to D, filled with Mercury from thence to B, and from thence to E with Water;

ter: Then, if the Tube FC be a little more than five Times leſs in Diameter than the Tube FA, the Variation in the lower Surface of the Water at E will be infinite; if it be above ſo many Times leſs, it will be more than infinite, otherwiſe it will be finite. See the Demonſtration in the Note *.

That

* Let v denote a given Variation in the common Barometer, x the correſpondent Variation at E ſought. Let the Ratio of m to 1, expreſs that of the ſpecific Gravity of Mercury, to that of Water; and d to 1, that of the Diameter of the Tube FA to FC. Then the Variation at E, the lower Surface of the Water, being ſuppoſed x, the Variation of it at B, the upper Surface of it will be $\frac{x}{dd}$, and conſequently GE, the Difference of the Legs EK and KB, will vary $x+\frac{x}{dd}$. Again, the Variation of the Surface of the Mercury at B will be the ſame with that of the Water in the ſame Place, *viz.* $\frac{x}{dd}$; and, if the Tube is of the ſame Diameter at D, as at B, the Variation of the Surface at D will alſo be the ſame, that is, $\frac{x}{dd}$: The Sum of both Variations, or the Variation of HD the Difference of the Legs, will therefore be $\frac{2x}{dd}$. Now the Preſſure of the Mercury and Water together upon the Air at E, is owing to the Lengths of HD and GE; and ſince one of theſe will always ſhorten, when the other lengthens, the Variation in their Preſſure will depend on the Variation of the Difference of their Weights, that is, of the Difference between the Weight of $x+\frac{x}{dd}$ and of $\frac{2x}{dd}$. But the Weight of $x+\frac{x}{dd}$ (being the Weight of a Column of Water) compared to that of a Column of Mercury of the ſame Length, is only $\frac{x+\frac{x}{dd}}{m}$. The Difference therefore between

That the Variation in this Barometer may be infinite, will appear from the following Computation.

Let the Proportion between the Bores of the Tube AF and FC be ſuch, that when HD, the Difference of the Legs wherein the Mercury is contained, is augmented one Inch, GE the Difference of the Legs, wherein the Water is contained, ſhall be diminiſhed fourteen; then, as much as the Preſſure of the Mercury is augmented, that of the Water will be diminiſhed, and ſo the Preſſure of both taken together will remain as it was. And conſequently, after it has began to riſe, it will always have the ſame Tendency to riſe on, without ever coming to an *Æquilibrium* with the Air.

How far this Barometer will ſucceed in Practice, muſt be left to Experience to determine.

tween $\frac{x+\frac{x}{dd}}{m}$ and $\frac{2x}{dd}$ will always be equal to the Variation in the common Barometer, and therefore $\frac{2x}{dd} - \frac{x+\frac{x}{dd}}{m} = v$, and by the common Method of Reduction, $x = \frac{vmdd}{2m-dd-1}$: That is, $x : v :: mdd : 2m-dd-1$. Now, if we put $m=14$, and $d=5$, 2, $-dd$ and -1 will be as much as $2m$, and therefore $2m-dd-1$ will be equal to nothing; and ſo x being by the Proportion as many Times more than v, as mdd is than nothing, 'tis infinite. And if m be put $=14$, and $d=5$, mdd will be equal to 350, and $2m-dd-1=2$; and therefore the Variations, in this Caſe, will be to thoſe in the common Barometer, as 175 to one.

Pro-

Probably, if the Bore of the Tube FC be made very ſmall, *viz.* about the twentieth Part of an Inch Diameter, the Air will not aſcend through the Water, as it is apt to do through the Mercury in the pendent Barometer; and the Smallneſs of the Bore will not prevent the Water, from moving, near ſo much as it does the Mercury in that Barometer.

There is an Improvement of another Kind in the common Barometer, whereby it is rendered *portable*. The Tube containing the Mercury, inſtead of having its lower End immerged in a Veſſel of that Fluid, has it tied up in a leathern Bag, not quite full of Mercury. And though the external Air cannot get into the Bag to ſuſpend the Mercury in the Tube, by preſſing on its Surface, as in the common one; yet it has the ſame Effect by preſſing on the Outſide of the Bag, which, being pliant, yields to the Preſſure, and keeps the Mercury ſuſpended in the Tube at its proper Height. This Bag is generally incloſed in a little Box, through the Bottom of which paſſes a Screw; with this Screw the Bag may be compreſſed, ſo as to force the Mercury up to the Top of the Tube; which keeps it ſteady, and hinders it from breaking the Tube by daſhing againſt the Top when it is carried about, as it otherwiſe would be apt to do.

See more on the Subject of this Diſſertation, *Weidleri* Inſtitutiones Mathemat. p. 608. *Melchior Verdries* Phyſ. Pars ſpecialis, Cap. IV. §. 15. Mr. *Paſchal*'s Traitè de l'Equilibre des Liqueurs. *Sinclair*'s Ars magna Gravitatis & Levitatis. *Mariotte*'s Second Eſſay de la Nature de l'Air. Philoſoph. Burgund. Tom. II. p. 850. *Saul*'s Treatiſe on the Barometer. *Regnault*'s Philoſoph. Converſat. 22. *Clare*'s Motion of Fluids, p. 141. Mem. de l'Acad. 1705, 1711. Philoſophical Tranſactions N°. 9, 10, 11, 55, 86, 91, 165, 181, 185, 208, 229, 236, 237, 240, 243, 269, 351, 366, 385, 388, 405, 406, 427. *Cotes*'s Hydroſtatical and Pneumatical Lecture. Lect. 7. With ſeveral other Authors referred to in Mr. *Johnſon*'s Quæſtiones Philoſophicæ, Cap. VI. Quæſt. 36, 37.

DIS-

DISSERTATION V.

Of the Origin of the Winds.

THE Wind is no other, than the Motion of the Air, upon the Surface of the Globe. Some of the Ancients took it to be Air, ruſhing out of the Bowels and Cavities of the Earth: And others thought it an Exhalation from its Surface. But theſe are *Hypotheſes* too chimerical to ſtand in Need of a particular Confutation. Some of the Moderns, who held a *Plenum*, have accounted for it thus. They imagined, that the Air being confined above, as it muſt be, if we ſuppoſe a *Plenum*, would, when more than ordinarily rarefied, or ſtocked with Vapours, drive away the neighbouring Air, in order to make room for itſelf; and by this Means occaſion a Wind. Others, obſerving a conſtant and perpetual eaſterly Wind to blow at the *Equator*, aſcribed its Origin to the diurnal Rotation of the Earth, about its Axis from Weſt to Eaſt; which they thought would occaſion the Air upon its Surface, to ſeem to move the contrary Way, being in ſome Meaſure left behind. But, whereas there are Winds, in ſome Places near the *Equator*,

that blow on other Points of the Compaſs (as we ſhall ſee hereafter) this *Hypotheſis* is inſufficient. Beſides, the Air preſſing upon the Surface of the Earth by its Gravity, like other Bodies; and having nothing to hinder it from moving freely along with it, muſt neceſſarily, in Time, acquire an equal Degree of Velocity, and ſo keep Pace with it, all the Way round.

The principal Cauſe of the Wind, or, in other Words, of the Air's moving from Place to Place, upon the Surface of the Earth, is the Atmoſphere's being heated over one Part more than over another. For, in this Caſe, the warmer Air, being rendered ſpecifically lighter than the reſt, riſes up into the ſuperior Parts of the Atmoſphere, and there diffuſes itſelf every Way; while the neigbouring inferior Air ruſhes in from all Parts at the Bottom, to reſtore the *Æquilibrium*.

Upon this Principle it is, that moſt of the Winds may be accounted for.

To begin with thoſe which blow under the *Equator*.

1. Under the *Equator*, the Wind is always obſerved to blow from the Eaſt Point *.

For,

* For the Reader's Eaſe (who perhaps is not furniſhed with the Philoſophical Tranſactions) I ſhall here inſert by Way of Note, from Dr. *Halley*'s Account, ſo much of the Hiſtory of the Winds, as may be neceſſary for the underſtanding this Theory.

" The

For, ſuppoſing the Sun to continue vertical over ſome one Place, the Air will be moſt rarefied there; and conſequently, the neighbouring

" The univerſal Ocean, ſays he, may moſt properly be divided " into three Parts, *viz.* 1. The *Atlantic* and *Æthiopic* Seas. " 2. The *Indian* Ocean. 3. The great *South* Sea, or the *Pacific* " Ocean.

" I. In the *Atlantic* and *Æthiopic* Seas, between the *Tropics*, " there is a general eaſterly Wind all the Year long, without " any conſiderable Variation; excepting, that it is ſubject to be " deflected therefrom, ſome few Points of the Compaſs, towards " the North, or South, according to the Poſition of the Place.

" 1. Near the Coaſt of *Africa*, as ſoon as you have paſſed the " *Canary* Iſles, you are ſure to meet a freſh Gale of North-eaſt " Wind, about the Latitude of twenty-eight Degrees North; " which ſeldom comes to the Eaſtwards of the Eaſt-north-eaſt, " or paſſes the North-north-eaſt. This Wind accompanies thoſe " bound to the Southward, to the Latitude of ten Degrees North, " and about an hundred Leagues from the *Guinea* Coaſt; where, " till the fourth Degree of North Latitude, they fall into *Calms* " and *Tornadoes*, or ſudden Storms.

" 2. Thoſe bound to the *Caribbe* Iſles, find, as they approach " the *American* Side, that the aforeſaid North-eaſt Wind be- " comes ſtill more and more eaſterly, ſo as ſometimes to be Eaſt, " ſometimes Eaſt by South, but yet moſt commonly to the North- " ward of the Eaſt, a Point or two, ſeldom more. 'Tis likewiſe " obſerved, that the Strength of theſe does gradually decreaſe, " as you ſail to the Weſtward.

" 3. That the Limits of the *Trade* and *variable* Winds in " this Ocean, are farther extended on the *American* Side, than " the *African*; for, whereas you meet not with this certain " Wind, till after you have paſs'd the Latitude of twenty eight " Degrees on this Side; on the contrary Side it commonly holds " to thirty, thirty-one, or thirty-two Degrees of Latitude; and this " is verified likewiſe to the Southward of the *Æquinoctial*; for " near the *Cape of Good Hope*, the Limits of the *Trade* Winds are " three or four Degrees nearer the *Line*, than on the Coaſt " of *Brazil*.

ing Air will ruſh in from every Quarter with equal Force. But, as the Sun is continually ſhifting to the Weſtward, the Part, where the Air

" 4. That from the Latitude of four Degrees North, to " the aforeſaid Limits on the South Side of the *Equator*, the " Winds are generally and perpetually between the South " and Eaſt, and moſt commonly between the South-eaſt and " Eaſt; obſerving always this Rule, that on the *African* Side, " they are more ſoutherly, on the *Braſilian* more eaſterly, ſo as " to become almoſt due Eaſt, the little Deflection they have be- " ing ſtill to the Southward. In this Part of the Ocean, it " has been my Fortune to paſs a full Year, in an Employ- " ment that obliged me to regard more than ordinarily the " Weather, and I found the Winds conſtantly about the " South-eaſt, the moſt uſual Point South-eaſt by Eaſt: When " it was eaſterly, it generally blew hard, and was gloomy, " dark, and ſometimes rainy Weather: If it came to the South- " wards, it was generally ſerene, and a ſmall Gale next to a " Calm; but this not very common. But I never ſaw it to the " Weſtwards of the South, or Northwards of the Eaſt.

" 5. That the Seaſon of the Year has ſome ſmall Effect on " theſe *Trade* Winds; for that when the Sun is conſiderably to " the Northward of the *Equator*, the South-eaſt Winds, eſpe- " cially in the Streight of this Ocean (if I may ſo call it) " between *Braſil*, and the Coaſt of *Guinea*, do vary a Point or " two to the Southward, and the North-eaſt become more " eaſterly; and, on the contrary, when the Sun is towards the " *Tropic* of *Capricorn*, the South-eaſterly Winds become more " eaſterly, and the North-eaſterly Winds, on this Side the " *Line*, veer more to the Northward.

" 6. That as there is no general Rule, that admits not of ſome " Exception, ſo there is in this Ocean a Tract of Sea, wherein " the ſoutherly and South weſt Winds are perpetual, *viz.* all " along the Coaſt of *Guinea*, for above five hundred Leagues to- " gether, from *Sierra Leona*, to the Iſle of St. *Thomas*: For " the South-eaſt *Trade* Wind having paſs'd the *Line*, and ap- " proaching the Coaſt of *Guinea* within eighty or an hundred " Leagues, inclines towards the Shore, and becomes South-ſouth- " eaſt; and by Degrees, as you come nearer, it veers about to " South, South-ſouth-weſt, and in with the Land South-weſt, and

" ſometimes

Air is moſt rarefied, is carried the ſame Way: and therefore the Tendency of all the lower Air, taken together, is greater that Way, than any other.

" ſometimes Weſt-ſouth-weſt. Theſe are the Winds, which are " obſerved on this Coaſt when it blows true; but there are fre- " quent Calms, violent ſudden Guſts, called *Tornadoes*, from all " Points of the Compaſs, and ſometimes unwholſome foggy " eaſterly Winds, called *Hermitæ*, by the Natives, which too " often infeſt the Navigation of theſe Parts.

" 7. That to the Northwards of the *Line*, between four and " ten Degrees of Latitude, and between the Meridians of *Cape* " *Verde*, and of the eaſtermoſt Iſlands that bear that Name, there " is a Tract of Sea, wherein it were improper to ſay, there is " any *Trade* Wind, or yet a *variable*; for it ſeems condemned to " perpetual Calms, attended with terrible Thunder and Light- " ning, and Rains ſo frequent, that our Navigators from thence " call this Part of the Sea, the *Rains*: The little Winds that " are, being only ſome certain Guſts, of very little Conti- " nuance, and leſs Extent; ſo that ſometimes each Hour you " ſhall have a different Gale, which dies away into a Calm " before another ſucceeds: And in a Fleet of Ships in Sight of " one another, each ſhall have the Wind from a ſeveral Point of " the Compaſs: With theſe weak Breezes, Ships are obliged to " make the beſt of their Way to the Southward, through the " aforeſaid ſix Degrees; wherein it is reported ſome have been " detained whole Months for want of Wind. ———

" II. In the *Indian* Ocean, the Winds are partly general, " as in the *Æthiopic* Ocean; partly periodical, that is, half " the Year they blow one Way, and the other half, near upon " the oppoſite Points; and theſe Points and Times of ſhifting, " are different in different Parts of this Ocean.

" 1. Between the Latitudes of ten Degrees and thirty Degrees " South, between *Madagaſcar* and *Hollandia nova*, the *Gene-* " *ral* Trade-Winds about the South-eaſt and by Eaſt, are found " to blow all the Year long, to all Intents and Purpoſes, " after the ſame Manner, as in the ſame Latitudes in the " *Æthiopic* Ocean, as it is deſcribed in the fourth Remark " aforegoing.

" 2. That

other. Thus the Tendency of the Air towards the Weſt, becomes general, and its Parts impelling one another, and continuing to move

" 2. That the aforeſaid South-eaſt Winds extend to within " two Degrees of the *Equator*, during the Months of *June*, " *July*, and *Auguſt*, &c. to *November*, at which Time, between " the South Latitude of three and ten Degrees, being near the " *Meridian* of the North End of *Madogaſcar*, and between two " and twelve South Latitude, being near *Sumatra* and *Java*; " the contrary Winds from the North-weſt, or between the " North and Weſt, ſet in, and blow for half a Year, *viz.* " from the Beginning of *December* till *May*: And this *Mon-* " *ſoon* is obſerved as far as the *Molucca* Iſles.

" 3. That to the Northward of three Degrees South Lati- " tude, over the whole *Arabian* and *Indian* Sea, and Gulf of " *Bengal*, from *Sumatra* to the Coaſt of *Africa*, there is another " *Monſoon*, blowing from *October* to *April*, upon the North- " eaſt Points: But in the other half Year, from *April* to *October*, " upon the oppoſite Points of South-weſt and Weſt-ſouth-weſt, " and that with rather more Force than the other, accompanied " with dark, rainy Weather; whereas the North-eaſt blows clear. " 'Tis likewiſe to be noted, that the Winds are not ſo conſtant, " either in Strength or Point, in the Gulf of *Bengal*, as they " are in the *Indian* Sea, where a certain ſteady Gale ſcarce ever " fails. 'Tis alſo remarkable, that the South-weſt Winds, in " theſe Seas, are generally more ſoutherly on the *African* Side, " and more weſterly on the *Indian*.

" 4. There is a Tract of Sea to the Southwards of the " *Equator*, ſubject to the ſame Changes of the Winds, *viz.* " near the *African* Coaſt, between it and the Iſland *Madogaſcar*, " or St. *Laurence*, and from thence Northwards, as far as the " *Line*; wherein from *April* to *October*, there is found a con- " ſtant freſh South-ſouth-weſt Wind, which, as you go more " northerly, becomes ſtill more and more weſterly, ſo as to fall " in with the Weſt-ſouth-weſt Winds, mentioned before in thoſe " Months of the Year to be certain to the Northward of the " *Equator*. What Winds blow in thoſe Seas, for the other " half Year, I have not yet been able to obtain to my full Satiſ- " faction: The Account which has been given me, is only this,

" That

move till the next Return of the Sun, ſo much of its Motion as was loſt by his Abſence, is again reſtored, and therefore the eaſterly Wind becomes *Perpetual.*

Some

" That the Winds are much eaſterly hereabouts, and as often to " the North of the true Eaſt, as to the Southward thereof.

" 5. That to the Eaſtward of *Sumatra* and *Malacca*, to the " Northwards of the *Line*; and along the Coaſt of *Camboia* " and *China*, the *Monſoons* blow North and South; that is to " ſay, the North-eaſt Winds are much northerly, and the " South-weſt much ſoutherly. This Conſtitution reaches to the " Eaſtward of the *Philippine* Iſles, and as far northerly as " *Japan*; the northern *Monſoon* ſetting in, in theſe Seas, in " *October* or *November*; and the ſouthern in *May*, blowing all " the Summer Months. Here it is to be noted, that the Points of " the Compaſs from whence the Winds come, in theſe Parts of " the World, are not ſo fixed, as thoſe lately deſcribed; for the " ſoutherly will frequently paſs a Point or two to the Eaſtwards " of the South, and the northerly as much as to the Weſtwards " of the North, which ſeems occaſioned by the great Quantity " of Land which is interperſed in theſe Seas.

" 6. That in the ſame Meridians, but to the Southwards of " the *Equator*, being that Tract lying between *Sumatra* and " *Java* to the Weſt, and New *Guinea* to the Eaſt, the ſame " northerly and ſoutherly *Monſoons* are obſerved; but with this " Difference, that the Inclination of the northerly is towards " the North-weſt, and of the ſoutherly towards the South-eaſt: " But the *Plagæ Venti* are not more conſtant here than in the " former, *viz. variable* five or ſix Points. Beſides, the Times of " the Change of theſe Winds are not the ſame, as in the *Chineſe* " Seas, but about a Month, or ſix Weeks later.

" 7. That the contrary Winds do not ſhift all at once, but in " ſome Places the Time of the Change is attended with *Calms*, " in others with *variable* Winds; and it is particularly remark- " able, that the End of the weſterly *Monſoon*, in the Seas of " *China*, are very ſubject to be tempeſtuous. The Violence of " theſe Storms is ſuch, that they ſeem to be of the Nature of the " *Weſt-India* Hurricanes, and render the Navigation of theſe Parts " very unſafe about that Time of the Year. Theſe Tempeſts are

" by

Some are inclined to think, that the continual ſhifting of the Sun to the Weſtward, ſhould produce a weſterly Wind under the *Equator*, by cauſing the Current of the Air from the Weſt to exceed and over-balance that,

" by our Seamen, uſually term'd the *Breaking up of the Mon-*
" *ſoons.*

" III. The Third Ocean, called *Mare Pacificum*, whoſe Ex-
" tent is equal to that of the other two (it being from the Weſt
" Coaſt of *America* to the *Philippine* Iſlands, not leſs than an hun-
" dred and fifty Degrees of Longitude) is that which is leaſt
" known to our own, or the neighbouring Nations: That Navi-
" gation that there is on it, is by the *Spaniards*; who go
" yearly from the Coaſt of *New-Spain* to the *Manilha*'s: But
" that but by one beaten Track; ſo that I cannot be ſo particular
" here, as in the other Two. What the *Spaniſh* Authors ſay of
" the Winds, they find in their Courſes; and what is confirmed
" by the old Accounts of *Drake* and *Candiſh*, and ſince by
" *Schooten*, who ſailed the whole Breadth of this Sea, in the
" ſouthern Latitude of fifteen or ſixteen Degrees, is, that there is
" a great Conformity between the Winds of this Sea, and thoſe
" of the *Atlantic* and *Ethiopic*; that is to ſay, that to the North-
" ward of the *Equator*, the predominant Wind is between
" the Eaſt and North-eaſt; and to the Southwards thereof, there
" is a conſtant, ſteady Gale, between the Eaſt and South-eaſt,
" and that on both Sides the *Line*, with ſo much Conſtancy, that
" they ſcarce ever need to attend the Sails; and ſtrength, that it
" is rare to fail of croſſing this vaſt Ocean in ten Weeks
" Time; which is about an hundred and thirty Miles a Day;
" Beſides, 'tis ſaid, that Storms and Tempeſts are never known
" in theſe Parts, wherefore ſome have thought it might be as
" ſhort a Voyage to *Japan* and *China*, to go by the Streights of
" *Magellan*, as by the Cape of *Good Hope*.

" The Limits of theſe *General* Winds are much the ſame
" as in the *Atlantic* Sea, *viz.* about the thirtieth Degree of La-
" titude on both Sides. Beſides, a farther Analogy between the
" Winds of this Ocean, and the *Ethiopic*, appears in that,
" that upon the Coaſts of *Peru*, they are always much ſoutherly,
" like as they are found near the Shores of *Angola*.

which

which oppoſes it from the Eaſt. For, whereas the eaſtern Air retains its Heat ſome time after the Sun is removed from it, it muſt always be rarefied to a greater Degree, and alſo to a greater Diſtance from the Place to which the Sun is vertical, than the weſtern Air is; and therefore the weſtern Air, being more ponderous, ſhould be an Over-balance for the eaſtern, and drive its Current before it.

But it is to be obſerved, that we are not to conſider the Point to which the Sun is vertical, but the Point of greateſt Rarefaction (which, upon Account of the Sun's Motion to the Weſtward, lies always to the Eaſtward); and then ſee, which Side of the Column of Air, incumbent over that Point, ſuſtains the greater Preſſure from the neighbouring Columns. Now, although the Air is rarefied even farther to the Eaſt of this Point, than to the Weſt, yet ſtill, if we ſuppoſe the Point to keep its place, the Air over it will ſuſtain an equal Degree of Preſſure on each Side. For, ſince no Column can be aſſigned on the weſtern Side, but one alſo on the eaſtern, may be found under an equal Degree of Rarefaction, and therefore of the ſame ſpecific Gravity: And ſince Fluids of equal Heights, and the ſame ſpecific Gravities (whatever be the Breadth of their Columns) preſs equally againſt equal Objects, (Chap. I. §. 9.) 'tis very evident, that the Column of Air, over the

Point of greateſt Rarefaction, is preſſed equally both Ways; and ſo, upon this Suppoſition, each Wind will blow towards that Point with equal Force. But, if we ſuppoſe the Point of greateſt Rarefaction to ſhift towards the Weſt, we ſhall find, that this *Æquilibrium* will by that Means be deſtroyed, and the Motion of the Air (upon the whole) determined that Way. For let us conſider any Portion of the weſtern Air approaching towards the Point of greateſt Rarefaction, if that Point ſhifts, in the mean Time, towards the Weſt, then will that Portion reach the ſaid Point ſooner than it otherwiſe would have done; thereby loſing a Part of its Motion, by which Means the weſterly Current will be diminiſh'd. Again, if, while the Eaſt Wind blows towards the Point of greateſt Rarefaction, that Point moves on before it, then will the eaſtern Air have a greater Quantity of Motion, than it otherwiſe would have had; that, which ſhould have been an Impediment to it, being, upon this Suppoſition, in ſome Meaſure withdrawn; and ſo the Eaſt Wind will be augmented. Thus, the Weſt Wind having its Force leſſen'd by the Motion of the Sun, and the Eaſt one being increaſed, the latter at length as it were abſorbs the former, and carries it away in its own Direction.

2. On each Side of the *Equator*, to about the thirtieth Degree of Latitude, the Wind is found

found to vary from the Eaſt Point, ſo as to become North-eaſt on the northern Side, and South-eaſt on the ſouthern.

The Reaſon of which is, that, as the *equatorial* Parts are hotter than any other, both the northern and ſouthern Air, ought to have a Tendency that Way; the northern Current therefore, meeting in this Paſſage with the eaſtern, produces a North-eaſt Wind on that Side; as the ſouthern Current joining with the ſame, on the other Side the *Equator*, forms a South-eaſt Wind there.

Theſe two Propoſitions are to be underſtood of open Seas, and of ſuch Parts of them as are diſtant from the Land; for near the Shores, where the neighbouring Air is much rarefied, by the Reflection of the Sun's Heat from the Land, it frequently happens otherwiſe particularly.

3. On the *Guinea* Coaſt, the Wind always ſets in upon the Land, blowing weſterly inſtead of eaſterly. This is becauſe the Deſerts of *Africa* lying near the *Equator*, and being a very ſandy Soil, reflect a great Degree of Heat into the Air above them. This therefore being rendered lighter, than that which is over the Sea, the Wind continually ruſhes in upon the Land to reſtore the *Æquilibrium*.

4. That Part of the Ocean, which is called the *Rains*, is attended with perpetual Calms, the Wind ſcarce blowing ſenſibly either one

Way or other. (See its Situation deſcribed in Note, Page 119, Remark 7th). For this Tract being placed between the weſterly Wind blowing from thence towards the Coaſt of *Guinea*; and the eaſterly Wind blowing from the ſame Place to the Weſtward thereof, the Air ſtands in *Æquilibrio* between both, and its Gravity is ſo much diminiſhed thereby, that it is not able to ſupport the Vapour it contains, but lets it fall in continual Rain, from whence this Part of the Ocean has its Name.

5. There is a Species of Winds, obſervable in ſome Places within the *Tropics*, called by the Sailors *Monſoons*, which, during ſix Months of the Year, blow one Way; and the remaining ſix, the contrary.

The Occaſion of them in general is this: When the Sun approaches the northern *Tropic*, there are ſeveral Countries, as *Arabia*, *Perſia*, *India*, &c. which become hotter, and reflect more Heat than the Seas beyond the *Equator*, which the Sun has left; the Winds therefore, inſtead of blowing from thence to the Parts under the *Equator*, blow the contrary Way; and when the Sun leaves thoſe Countries, and draws near the other *Tropic*, the Winds turn about, and blow on the oppoſite Point of the Compaſs.

The Regularity of theſe Winds making them more than ordinarily uſeful in Navigation, they are from thence called *Trade* Winds.

Winds. As to other Circumſtances relating to them, and the particular Times and Places of the *Monſoons*, &c. See the Hiſtorical Account in the foregoing Note; all which might eaſily be ſolved upon the ſame Principle, had we *Data* to go upon, and were all the ſeveral Circumſtances of Situation, Heat, Cold, *&c.* ſufficiently known *.

From the Solution of the general *Trade* Winds, we may ſee the Reaſon, why in the *Atlantic* Ocean, a little on this Side the thirtieth Degree of North Latitude, or thereabouts, as was obſerved in the foregoing Diſſertation, there is generally a Weſt, or South-weſt Wind. For, as the inferior Air, within the Limits of thoſe Winds, is conſtantly ruſhing towards the *Equator*, from the North-eaſt Point, or thereabouts, the ſuperior Air moves the contrary Way; and therefore after it has reached theſe Limits, and meets with Air, that has little or no Tendency to

* Some have thought, that the Regularity of the general *Trade* Winds is partly owing to the diurnal Motion of the Moon from Eaſt to Weſt. For, as the Sun renders the Air ſpecifically lighter by its Heat, ſo does the Moon by attracting it, in the ſame Manner, as it does the Sea, in raiſing the Tides. But it is to be obſerved, that as the Moon acts with the greateſt Force upon the ſuperior Parts of the Air, and as thoſe ſuperior Parts are unconfined, and therefore more at Liberty to ruſh in, in Order to reſtore the *Æquilibrium*; it will from hence follow, that the ruſhing in of the ſuperior Parts of the Atmoſphere will principally contribute towards reſtoring the *Æquilibrium*; and ſo the Motion produced below, will be very inconſiderable.

any

any one Point more than to another, by Reaſon of the Sun's Diſtance, it will determine it to move in the ſame Direction with itſelf.

In our own Climate we frequently experience, in calm Weather, gentle Breezes blowing from the Sea to the Land, in the Heat of the Day; which *Phænomenon* is very agreeable to the Principle laid down above: For the inferior Air over the Land being rarefied by the Beams of the Sun, reflected from its Surface, more than that which impends over the Water which reflects fewer, the latter is conſtantly moving on to the Shore, in order to reſtore the *Æquilibrium*, when not diſturbed by ſtronger Winds from another Quarter *.

From what has been obſerved, nothing is more eaſy than to ſee, why the northern and ſouthern Parts of the World, beyond the Limits of the *Trade* Winds, are ſubject to ſuch

* In Confirmation of this, we have an eaſy, and very pertinent Experiment, related by Mr. *Clare*, in his *Motion of Fluids*. "Take, *ſays he*, a large Diſh, fill it with cold Water; into the "Middle of this put a Water-Plate, filled with warm Water. "The firſt will repreſent the Ocean; and the other an Iſland, "rarefying the Air above it. Blow out a Wax Candle, and if "the Place be ſtill, on applying it ſucceſſively to every Side of "the Diſh, the fuliginous Particles of the Smoak, being viſible "and very light, will be ſeen to move towards the Plate, "and riſing over it, point out the Courſe of the Air from Sea "to Land. Again, if the ambient Water be warmed, and the "Plate filled with cold Water, let the ſmoaking Wick of the "Candle be held over the Plate, and the contrary will happen.

Variety

Variety of Winds. For the Air, upon Account of its Diſtance from the *Equator*, being undetermined to move towards any fixed Point, is continually ſhifting from Place to Place, in Order to reſtore the *Æquilibrium*, wherever it is deſtroyed; whether by the Heat of the Sun, the riſing of Vapours, or Exhalations, the melting of Snow upon the Mountains, and a great Variety of other Circumſtances, more than can be eaſily enumerated.

We are told by Hiſtorians, of certain Caves that emit Wind; if ſo, it is when the included Air is rarefied by Heat, and therefore ruſhes out for want of Room; or, when the Preſſure of the external Air, incumbent upon the Mouth of the Cave, is diminiſhed, and ſo permits the internal Air to dilate itſelf, and iſſue out.

For more on this Subject, ſee *Nieuwentyt*'s Religious Philoſopher. *Regnault*'s Philoſophical Converſations. *Clare*'s Motion of Fluids. *Martin*'s Philoſophical Grammar. And the Authors referred to in Mr. *Johnſon*'s Quæſtiones Philoſoph. Cap. IV. Quæſt. 1. 2.

DISSERTATION VI.

Of the Formation, and Aſcent of Vapours, and their Reſolution into Rain, Snow, *and* Hail.

THAT Vapours are raiſed from off the Surface of Water by the Action of the Sun's Heat, is agreed on by all: But the Manner in which this is done, has ever been a Controverſy among Philoſophers; neither is it at this Time ſufficiently explain'd by any one.

If we conſult a *Carteſian* upon this Matter, he immediately tells us, that, by the Action of the Sun upon the Water, ſmall Particles of the Water, are formed into hollow Spheres, filled with *Materia Subtilis*, and by that Means becoming lighter than an equal Bulk of Air, are eaſily buoyed up in it. But, as this *Materia Subtilis* is only a Fiction, the Solution is not to be regarded.

Dr. *Nieuwentyt*, and ſeveral other Philoſophers, who maintain, that Fire is a particular Subſtance, diſtinct from other Matter, account for the Formation and Aſcent of Vapours thus: They ſay, that the Rays of the Sun, or Particles of Fire ſeparated from them, adhering to Particles of the Water, make up

up little Bodies, lighter than an equal Bulk of Air; which therefore, by the Laws of Hydroſtatics, will aſcend in it, till they come to an Height where the Air is of the ſame ſpecific Gravity with themſelves. And, that Rain is produced by the Separation of the Particles of the Fire from thoſe of the Water; which laſt, being then left without Support, can no longer be ſuſtained by the Air, but falls down in Drops of Rain *.

This Opinion is liable to the following Difficulties; *Firſt*, Fire has never been yet proved to be a diſtinct Element, or a particular Subſtance †; and the Change of Weight in Bodies in chymical Preparations, heretofore thought to ariſe from the Adheſion of Particles of Fire, is found to proceed from the Adheſion of Particles of Air §.

Secondly, Should the above-mentioned Suppoſition be allowed, the fiery Particles, which are joined to the watery ones to buoy them up, muſt be conſiderably large, or elſe a very great Number muſt fix upon a ſingle Particle of Water; and then a Perſon, being on the Top of an Hill in a Cloud, would be ſenſible of the Heat, and find the Rain produced from that Vapour, much colder than the Vapour it-

* See *Nieuwentyt*'s Religious Philoſopher, Contempl. 19.

† See the Authors referred to in Mr. *Johnſon*'s Quæſtiones Philoſoph. Cap. I. Quæſt. 30.

§ By Dr. *Hales*, in his *vegetable Statics*.

ſelf: whereas the contrary is evident to our Senſes; the Tops of Hills, though in the Clouds, being much colder than the Rain which falls below.

Beſides, the Manner in which the Particles of Water ſhould be ſeparated from thoſe of the Fire, ſo as to fall in Rain, is not eaſily to be conceived.

The moſt generally received Opinion is, That by the Action of the Sun, on the Surface of the Water, the aqueous Particles become formed into Bubbles, filled with a *Flatus*, or *warm Air*, which renders them ſpecifically lighter than common Air, and makes them riſe therein, till they meet with ſuch as is of the ſame ſpecific Gravity with themſelves *. But I ask,

Firſt, How comes the Air in the Bubbles to be ſpecifically lighter than that without, ſince the Sun's Rays, which act upon the Water from whence they are raiſed, are equally denſe over all its Surface?

Secondly, If it could be poſſible for rarer Air to be ſeparated from the denſer ambient Air, to form the Bubbles (as Bubbles of ſoaped Water are blown up by warm Air from the Lungs, whilſt the ambient Air is colder and denſer) what would hinder the external Air from reducing that, which is incloſed in the Bubbles, immediately to the ſame Degree of

* Philoſophical Tranſactions, N°. 192.

Cold-

Coldneſs, and ſpecific Gravity with itſelf; (Cold being readily communicated through ſuch thin Shells of Water). By which means, the Bubbles would become ſpecifically heavier than the circumambient Air, and would no longer be ſupported therein; but fall down, almoſt as ſoon as they were formed?

Thirdly, If we ſhould grant all the reſt of the Suppoſition, yet the following Difficulty will ſtill remain. If Clouds are made up of Bubbles of Water filled with Air, why do not thoſe Bubbles always expand, when the ambient Air is rarefied, and preſſes leſs upon them than it did before; and why are they not condenſed, when the ambient Air is condenſed by the Accumulation of the ſuperior Air? But if this Condenſation and Rarefaction ſhould happen to them, the Clouds would always continue at the ſame Height, contrary to Obſervation; and we ſhould never have any Rain.

The two laſt Opinions are more largely examined by Dr. *Deſaguliers* in the Philoſophical Tranſactions N°. 407. After which he endeavours to eſtabliſh one of his own.

He obſerves, with Sir *Iſaac Newton*, that, when by Heat or Fermentation the Particles of a Body are ſeparated from their Contact, their repulſive Force grows ſtronger, and the Particles exert that Force at greater Diſtances; ſo that the ſame Body ſhall be expanded into a very large Space, by becoming fluid; and

may ſometimes take up more than a Million of Times the Room it did in a ſolid and incompreſſible State. "Thus, ſays he, if the "Particles of Water are turned into Vapour, "by repelling each other ſtrongly, and repel "Air more than they repel each other; Ag- "gregates of ſuch Particles, made up of Va- "pour and Vacuity, may riſe in Air of different "Denſities, according to their own Denſity "depending on their Degree of Heat." He obſerves farther, that Heat acts more powerfully on Water, than on common Air; for that the ſame Degree of Heat, which rarefies Air two Thirds, will rarefy Water near fourteen thouſand Times, changing it into Steam or Vapour as it boils it. And in Winter, that ſmall Degree of Heat, which in Reſpect of our Bodies appears cold, will raiſe a Steam or Vapour from Water, at the ſame Time that it condenſes Air. Laſtly, he obſerves, That the Denſity and Rarity of this Vapour depends chiefly on its Degree of Heat, and but little on the Preſſure of the circumambient Air. From all which he infers, That the Vapour being more rarefied near the Surface of the Earth, than the Air is there by the ſame Degree of Heat, muſt neceſſarily be buoyed up into the Atmoſphere; and ſince it does not expand itſelf much, though the Preſſure of the incumbent Air grows leſs, at length it finds a Place where the Atmoſphere is of the ſame ſpecific

Gravity

Gravity with itſelf, and there floats, till by ſome Accident or other, it is converted again into Drops of Water, and falls down in Rain.

And to ſhew that Air is not neceſſary for the Formation of Steam or Vapour, he gives us this Experiment.

" ABCD (*Fig.* 37.) is a pretty large Veſ-
" ſel of Water, which muſt be ſet upon the
" Fire to boil. In this Veſſel muſt be ſuſpend-
" ed the Glaſs Bell E, made heavy enough
" to ſink in Water ; but put in, in ſuch a Man-
" ner, that it be filled with Water when up-
" right, without any Bubbles of Air at its
" Crown within, the Crown being all under
" Water. As the Water boils, the Bell will
" by Degrees be emptied of its Water, being
" preſſed down by the Steam, which riſes
" above the Water in the Bell; but, as that
" Steam has the Appearance of Air, in Order
" to know whether it be Air or not, take the
" Veſſel off the Fire, and draw up the Bell
" by a String faſtened to its Knob at Top,
" till only the Mouth remains under Water ;
" then as the Steam condenſes by the cold
" Air on the Outſide of the Bell, the Water
" will riſe up into the Bell at F, quite to the
" Top, without any Bubble above it ; which
" ſhews, that the Steam, which kept out the
" Water, was not Air. "

This

This Hypotheſis, howevever plauſible it may appear, is attended with Difficulties, as well as the other. For,

Firſt, If the repulſive Power of the Particles of Water is ſufficiently augmented by Heat as ſuch (and that by a very ſmall Degree of it) to make them recede from each other, and become ſpecifically lighter than common Air; how comes it to paſs, that all the Particles of Water, as ſoon as, or before it boils, have not their repulſive Forces thus augmented, ſince they are all under a much greater Degree of Heat, than is neceſſary to raiſe Vapour?

Secondly, Allowing that they may riſe off from the Surface of the Water, and float in the circumambient Air, as being lighter than it, why do not their repulſive Forces, as they riſe up into the Air, and the ſuperincumbent Preſſure becomes leſs, drive them to greater Diſtances from each other, and ſo cauſe them to continue lighter than the Air about them at all Heights?

Thirdly, If the Preſſure of the Air about them, when near the Surface of the Earth, is not ſufficient to bring them into ſo cloſe Contact, as to form Drops of Water there, what Force will they find ſufficient for it, when they are carried aloft into a Region of Air, where the Preſſure is not near ſo great? The Doctor hints, that they are formed into Rain, "when "by the great Diminution of the ſpecific Gra-

"vity

" vity of the Air about a Cloud, it has a " great Way to fall, in which Caſe, he ſays, " the Reſiſtance of the Air, which increaſes " as the Square of the Velocity of the de- " ſcending Cloud, cauſes the floating Particles " of Water to come within the Power of each " other's Attraction, and form ſuch big Drops " as, being ſpecifically heavier than any Air, " muſt fall in Rain." But as the inferior Air, from the Cloud to a conſiderable Depth below it, cannot be ſuppoſed to leave it all at once, the Vapours muſt neceſſarily fall all the Way through a reſiſting *Medium*; ſo that the little Velocity the Cloud can acquire, while it is in the Form of Vapour, will never produce a Reſiſtance from the Air greater than the Preſſure which the Vapours ſuſtained below

Laſtly, The Experiment, brought to make Way for this Hypotheſis, ſhows clearly, that Vapour formed without the Reſiſtance of Air, is immediately condenſed into Water again, as ſoon as it is ſuffered to cool: Which is widely different from what happens to Vapours buoyed up into the colder Regions of the Air, and floating there, till they fall in Rain.

Theſe are all, or the principal *Hypotheſes*, that have been framed for the Solution of this common *Phænomenon:* Which as they ſeem inadequate to the Effects produced, and therefore unſatisfactory, I thought it not amiſs to ſug-

ſuggeſt to the Reader the chief Difficulties, with which I conceive them to be attended. But as it is eaſier to pull down, than to build up, to overturn a weak *Hypotheſis*, than to raiſe and ſupport a ſtrong and ſufficient one; ſo, I muſt own, in this Caſe, I can think of no Way of accounting for the Riſe of Vapours, according to the received Principles of Philoſophy, or ſay wherein their Nature conſiſts. Upon this Account it is impoſſible I ſhould give a Philoſophical Account of their Reſolution into Rain. It muſt ſuffice juſt to mention the Cauſes, which are obſerved to produce that Change.

The firſt is, That Part of the Air beneath them is carried away by contrary Winds blowing from the ſame Place*; for then the Remainder being too light to buoy them up, the upper ones, in all Probability, precipitate down upon the lower ones, unite with them, and forms Drops of Rain †. Another is, great Quan-

* Perhaps it may be thought, that when the Air, which impends over any Place, is carried away from thence by contrary Winds, the Vapours which float in it ſhould be carried away too; and ſo the few that remain ſhould be eaſily ſupported; or, if they fall, ſhould not produce much Rain.

Now, in Anſwer to this, it muſt be conſidered, that as the inferior Air is carried away from any Place by contrary Winds, the Height of the Atmoſphere is diminiſhed thereby; wherefore, in all Probability, the ſuperior Air ruſhes in by a contrary Current to fill up the Vacuity at the Top, which bringing in its Contents of Vapour affords a continual Supply for the Rain that falls.

† A remarkable Inſtance we have of this, in that Part of the *Atlantic* Ocean, which the Sailors call the *Rains*, (ſee Diſſert. V.) from

Quantities of them, being driven by the Winds againſt the Sides of Mountains, are thereby made to coaleſce, and ſo conſtitute Rain*.

It

from the frequent Rains that fall there: the Occaſion of which is, that the Atmoſphere is diminiſhed by continual contrary Winds blowing from thence, ſo that it is not able to ſuſtain the Vapour it receives.

* Upon this depends the Difference of the Seaſons of the Year at *Malabar* and *Coromandel* in the *Eaſt-Indies*, and at *Jamaica* in the Weſt. See Dr. *Gordon*'s Diſcourſe on the Cauſes of the Change of Weather, Philoſophical Tranſactions, N°. 17.——

"The Rivers of *Indus* and *Ganges*, ſays he, where they enter the "Ocean, contain between them a large *Cherſoneſus*, which is di- "vided in the Middle by a Ridge of Hills, which they call the "*Gate*, which run along from Eaſt to Weſt, and quite through to "Cape *Comori*. On the one Side is *Malabar*, and on the other *Co-* "*romandel*. On the *Malabar* Side, between that Ridge of Moun- "tains and the Sea, it is after their Appellation Summer from *Sep-* "*tember* till *April*; in which Time it is always a clear Sky, with- "out once, or very little Raining. On the other Side the Hills, on "the Coaſt of *Coromandel*, it is at the ſame Time their Winter, "every Day and Night yielding Abundance of Rain, and from "*April* to *September* it is, on the *Malabar* Side their Winter, and "on the other Side their Summer: So that in little more than twen- "ty Leagues Journey in ſome Places, as where they croſs the Hills "to St. *Thomas*, on the one Side of the Hill you aſcend with a "fair Summer; on the other you deſcend with a ſtormy Winter. "The like is ſaid to be at Cape *Razalgate* in *Arabia*. And Dr. "*Tropham* relates the ſame of *Jamaica*, intimating that there is "a Ridge of Hills which runs from Eaſt to Weſt, through the "midſt of the Iſland, and that the Plantations on the South Side "of the Hills have, from *November* to *April*, a continual Sum- "mer, whilſt thoſe on the North Side have as conſtant a "Winter, and the contrary from *April* to *November*.

"From theſe and ſuch like Accounts it ſeems evident, that a "bare leſſening of the Atmoſphere's Gravity will not occaſion "Rain, but that there is alſo needful either a ſudden Change of "Winds, or a Ridge of Hills to meet the Current of the Air and "Vapours, whereby the Particles of the Vapours are driven toge- "ther, and ſo fall down in Drops of Rain. And hence it is,

It is generally thought, That if the Vapours in their Deſcent paſs through a Region of Air ſufficiently cold, they are there frozen into Icicles,

" that whilſt the Wind blows from the North-eaſt, *viz.* from *November* to *April* (ſee the Account of the Monſoons in the foregoing Diſſertation) " there are continual Rains in the northerly " Plantations of *Jamaica*, and on the Side of *Coromandel* in " the *Eaſt-Indies*, becauſe the Winds beat againſt that Side of " the Hills; and ſo there is fair Weather on the other Side of " theſe Hills, in *Malabar* and in the ſouthern Plantations of *Jamaica*, there being no Winds to drive the Vapours together. " But in the ſoutherly Monſoons, *viz.* from *April* to *November*, " *Malabar* and the ſoutherly Plantations of *Jamaica* have Floods " of Rain, the Wind beating againſt that Side of the Hills, whilſt " in *Coromandel*, and the other Side of *Jamaica*, there is fair " and clear Weather.

" This ſerves alſo to clear the *Singularity* of *Seaſons* in *Peru*, be- " yond any other Parts of the Earth, and ſeems to be aſſigned by *Aco- " ſta* as the Cauſe of it. *Peru* runs along from the *Line* Southwards " about a thouſand Leagues. It is ſaid to be divided into three Parts, " long and narrow, which they call *Lanos*, *Sierras*, and *Andes*; the " *Lanos*, or Plains, run along the South-Sea Coaſt; the *Sierras* are " all Hills with ſome Vallies; and the *Andes* ſteep and craggy Moun- " tains. The *Lanos* have ſome ten Leagues in Breadth, in ſome " Parts leſs, and in ſome more; the *Sierras* contain ſome twenty " Leagues in Breadth, the *Andes* as much, ſometimes more, ſome- " times leſs; they run in Length from North to South, and in " Breadth from Eaſt to Weſt. This Part of the World is ſaid to " have theſe remarkable Things: 1. All along the Coaſt, in the " *Lanos*, it blows continually with one only Wind, which is South " and South-weſt, contrary to that which uſually blows under the " torrid Zone. 2. It never rains, thunders, ſnows, or hails in " all this Coaſt, or *Lanos*, though there falls ſometimes a ſmall " Dew. 3. Upon the *Andes* it rains almoſt continually, though " it be ſometimes more clear than other. 4. In the *Sierras*, " which lie between both Extreams, it rains from *September* to " *April*, but in the other Seaſons it is more clear, which is when " the Sun is fartheſt off, and the contrary when it is neareſt. " Now the Reaſon of all ſeems to be this; The eaſtern Breezes, " which blow conſtantly under the *Line*, being ſtopp'd in their

" Courſe

Icicles, and from Snow. But this Opinion ſeems to be falſe; becauſe it frequently ſnows when the Barometer is high, at which Time the Vapours cannot begin to fall. It is therefore more probable, that they are firſt frozen into Icicles, and by that means ſhooting forth into ſeveral Points every Way from the Center (agreeably to the Nature of Freezing) loſe their Form; and ſo becoming ſpecifically heavier than Air fall down, and in their Paſſage, ſeveral being congealed together, form Fleeces of Snow*.

Hail is evidently no other, than Drops of Rain congealed into Ice. This happens, when in their Paſſage through the inferior Air, they

" Courſe by the *Sierras* and *Andes*, and yet the ſame Breezes be-
" ing to be found in the South Sea beyond *Peru*, as appears by
" the eaſy Voyages from *Peru* to the *Philippines*, a Current of
" Wind blows from the South on the Plains of *Peru*, to ſupply
" the eaſtern Breeze on the South-Seas, and there being but one
" conſtant Gale on theſe Plains, and no contrary Winds or Hills
" for it to beat upon, this ſeems to be the Reaſon why the Va-
" pours are never or very ſeldom driven into Rain. And the
" *Andes* being as high perhaps in many Places as the Vapours
" aſcend in the higheſt Degree of the Atmoſphere's Gravity, this
" may probably be the Reaſon, why the eaſtern Breeze, beating
" conſtantly againſt theſe Hills, occaſions Rain upon them at all
" Seaſons of the Year. And the *Sierras* being it ſeems lower
" than the *Andes*, therefore from *September* to *April*, when the
" Sun is neareſt, and ſo the Atmoſphere's Gravity leſs, and the
" Vapours lower, they are driven againſt the *Sierras* into Rain.

The like is to be ſaid of other Countries. They are all, *cæteris paribus*, more or leſs rainy, as they are more or leſs mountainous. *Ægypt*, which is quite without Mountains, has ſeldom or never any Rain; but is plentifully watered by the *Nile*, which yearly riſes above its Banks, and overflows the whole Country.

* See a Diſcourſe on the Nature of Snow, Philoſophical Tranſactions N°. 92.

meet with *nitrous* Particles, which are known to contribute greatly to Freezing. Their Magnitude is owing to a freſh Acceſſion of Matter, as they paſs along. Hence we ſee the Reaſon why Hail is ſo frequent in Summer, becauſe at that Time greater Quantities of Nitre are exhaled from the Earth, and float up and down in the Air.

If the Vapours, after they are exhaled from off the Waters, do not riſe very high in the Atmoſphere, but hover near the Surface of the Earth, they then conſtitute what we call a Fog. And, if they aſcend higher, they ſtill appear in the ſame Form to thoſe, who, being upon the Tops or Sides of Mountains, are at an equal Height with them; though to thoſe, who are below, they appear as Clouds.

If they fall to the Earth, without uniting into Drops large enough to be called Rain, they are then ſaid to fall in Dew.

See farther on this Subject, *Derham*'s Phyſ. Theolog. Book I. Chap. 3, and Book II. Chap 5. Spectacle de la Nature, Dialog, 21, and 23. *Nieuwentyt* Contempl. 19. *Clare*'s Motion of Fluids. *Regnault*, Vol. III. Converſat. 7. *Muſſchenbroek* Epitom. Phyſ. Mathemat. Par. II. Cap. 24. *Melchior Verdries* Phyſic. Pars ſpecial. Cap. V. §. 8. And the Authors referred to in Mr. *Johnſon*'s Queſtiones Philoſoph. Cap. IV. Quæſt. 7.

DIS-

DISSERTATION VII.

Of the Cauſes of Thunder and Lightning, and of the Aurora Borealis.

THOSE Philoſophers, who maintain that Vapours are buoyed up into the Air, by Particles of Fire adhering to them (as explained in the foregoing Diſſertation) account for the *Phænomena* of Thunder and Lightning, in the following Manner. They ſuppoſe, that from the Particles of Sulphur, Nitre, and other combuſtible Matter, which are exhaled from the Earth, and carried into the higher Regions of the Atmoſphere, together with the aſcending Vapours, is formed an inflammable Subſtance; which, when a ſufficient Quantity of fiery Particles is ſeparated from the Vapour by the Colliſion of two Clouds, or otherwiſe, takes Fire, and ſhoots out into a Train of Light, greater or leſs, according to the Strength and Quantity of the Materials.

This Opinion is falſe for the Reaſons mentioned in the foregoing Diſſertation, which plainly ſhow, that it is impoſſible the Vapours ſhould be attended with ſuch fiery Particles, as is here ſuppoſed.

Neither

Neither have we Occaſion to fly to ſuch an *Hypotheſis*; for, as Vapours exhaled from the Surface of the Water are carried up into the Atmoſphere: in like Manner, the *Effluvia* of ſolid Bodies are continually aſcending thither: Now we find by Experiment, that there are ſeveral inflammable Bodies, which, being mixed together in due Proportion, will kindle into Flame by Fermentation alone,* without the Help of any fiery Particles †. When therefore

* See the Theory of Fermentation explained in the following Diſſertation.

† Monſieur *Lemery* having covered up in the Earth about fifty Pounds of a Mixture compoſed of equal Parts of Sulphur, and Filings of Iron tempered with Water; after eight or nine Hours Time, the Earth, where it was laid, vomited up Flames. Hiſt. de l'Acad. 1700, p. 574.

From this Experiment we ſee the true Cauſe of the Fire of *Ætna* and *Veſuvius*, and other burning Mountains. They probably are Mountains of Sulphur, and ſome other Matter proper to ferment with it, and take Fire. From like Cauſes proceeds the Heat of Bath-waters, and other hot Springs.

Mix a ſmall Quantity of Gun-Powder with Oyl of Cloves, pour gently upon this Mixture, two or three times as much Spirit of Nitre, and you will obſerve a bright Inflammation ſuddenly ariſing from it. A Mixture of the two Fluids alone will take Fire; the Powder is added only to augment the Inflammation.

Take two Pounds of Nitre, or refined Salt Petre well dried and reduced to the fineſt Powder, with a Pound of Oyl of common Vitriol: From this Mixture may be drawn by Diſtillation a Spirit of Nitre capable of inflaming Oyl of Turpentine. Mem. de l'Acad. 1726, p. 97, *&c.* Put into a Glaſs an Ounce of this Spirit of Nitre, with an Ounce of Oyl of Vitriol; pour upon it an equal Quantity of Oyl of Turpentine, and a very fine Flame will ariſe ſuddenly with a great Exploſion. When the Liquors are freſh the Effect is much greater. If we mix a Dram of the Spirit of Nitre and three of Oyl of Turpentine, with only one of the Spirit of

fore there happens to be a proper Mixture of the *Effluvia* of ſuch Bodies floating in the Air, they ferment, kindle, and flaſhing like Gunpowder, occaſion thoſe Exploſions, and Streams of Fire, which we call Thunder and Lightning.

As to the particular Species of *Effluvia*, which compoſe this Mixture, that cannot exactly be determined; they are thought to be chiefly ſulphureous and nitrous: *ſulphureous*, becauſe of the ſulphureous Smell which Lightning generally leaves behind it, and of that ſultry Heat in the Air which is commonly the Fore-runner of it: *nitrous*, becauſe we don't know of any Body ſo liable to a ſudden and violent Exploſion, as Nitre is *.

The

of Vitriol, the Mixture will take Fire immediately. If the ſame Experiment be made with the Balm of *Mecca*, a ſudden Flame will ariſe, with a Noiſe like that of the Report of a Gun.

There are two celebrated Experiments of this Kind, though they do not come up exactly to the preſent Purpoſe, becauſe they will not ſucceed, unleſs the Ingredients be firſt heated, the one of *Aurum fulminans*, and the other of *Pulvis fulminans*. The firſt is a Mixture of Salt of Tartar, and Gold diſſolved by *Aqua Regia*. A ſmall Quantity of this, if put into a Braſs Spoon, and heated with the Flame of a Candle, cauſes a ſudden Noiſe reſembling that of Thunder; and goes off with great Violence. The other is a Mixture of three Parts of Nitre, two of Salt of Tartar, and one of Sulphur. This Mixture when ſet upon the Fire, and warmed to a certain Degree, is diſſipated all on a ſudden with great Thundering, like the *Aurum fulminans*.

See an Account of Exhalations taking Fire of their own Accord in Cole-Pits. *Power*'s Experimental Philoſophy, p. 62. and 181.

* Dr. *Liſter* is of Opinion, That the Matter both of Thunder and Lightning, and alſo of Earthquakes, is the *Effluvia* of the *Pyrites*,

The Effects of Thunder and Lightning are owing to the ſudden and violent Agitation the Air is put into thereby, together with the Force of the Exploſion *; and not to Thunderbolts falling from the Clouds; as ſuppoſed by the Vulgar †.

Pyrites; as he does, that the Matter of *Vulcano*'s is the *Pyrites* itſelf. This is a Mineral that emits copious Exhalations, and is exceedingly apt to take Fire upon the Admiſſion of Moiſture. See the Doctor's Defence of his Notion in the Philoſophical Tranſactions, N° 157. He thinks this may be the Reaſon why *England* is ſo little troubled with Earthquakes, and *Italy*, and almoſt all Places round the *Mediterranean* Sea, ſo very much, *viz.* becauſe the *Pyrites* are rarely found in *England*; and where they are, they lie very thin, in Compariſon of what they do in thoſe Countries; as the vaſt Quantity of Sulphur, emitted from the burning Mountains there, ſeems to ſhew.

* Lightning is ſaid to have diſſolved Silver, without burning the Purſe it was in; and to have melted the Sword, without touching the Scabbard, and the like. The Occaſion of this may poſſibly be, that the Matter of the Exhalation may be ſo ſubtile and penetrating, that, as we ſee it happens with *Aqua Fortis*, or *volatile Salts*, it may paſs through ſoft Bodies without altering their Texture, while it ſpends its whole Force on hard ones, in which it finds the greater Reſiſtance.

† Some are inclined to think, that Thunderbolts are artificial, and that they were applied by the Ancients to ſome Uſe. What confirms them in their Opinion, is, that they are found more frequently where Sepulchres have been, than in other Places. And, as it was the Cuſtom of the Ancients to have their Arms buried with their Aſhes, they think they might be of ſome Uſe in War. Some are of Opinion, they were uſed in Sacrifices. See *Melchior Verdrie*'s Phyſic. Pars ſpecial. Cap. V. §. 9. *Wedelius* Exercit. Med. Philol. Cont. II. Dec. I. p. 103. *Schmincklius* Profeſſ. Marpurg. Diſſertat. de Urnis Sepulchralibus, & Armis Lapideis, A. 1714. *Herman Nunningius* Sepulchret. Weſtphal. Mimigard. Gentil. p. 44. *Jo. Henr. Coharſen* Oſſiteg. Hiſtor. Phyſic. p 44.

The

The Diſtance the Thunder is from us, may nearly be eſtimated by the Interval of Time between our ſeeing the Lightning, and hearing the Thunder. For, as the Motion of Light is ſo very quick, that the Time it takes up, in coming to us from the Cloud, is not perceptible; and as that of Sound is about a thouſand Feet in a Second; allowing a thouſand Feet for every Second, that paſſes between our ſeeing the one, and hearing the other; we have the Diſtance of the Cloud, pretty nearly, from whence the Thunder comes.

We ſometimes ſee Flaſhes of Lightning, though the Sky be clear and free from Clouds; in this Caſe they proceed from Clouds, that lie immediately below our Horizon.

Of Affinity with the *Phænomena* of Lightning are thoſe of the *Aurora Borealis*, or *Northern Lights*, which, of late Years, have very frequently appeared in our Climate *. Theſe Lights differ ſo much from each other, that to give a Deſcription of one alone, would not be

* *Phænomena* of this Kind are reported to have been very frequent in *Groenland*, *Iceland*, and *Norway*, Countries near the Pole. The only ones, that are upon Record, as having appeared in *England*, before that of *March* the 6th, $17\frac{15}{16}$, are thoſe of *January* the 30th, 1560, *October* the 7th, 1564. *November* 14th and 15th, 1574, and a ſmall one ſeen near *London* on the 9th of *Auguſt*, 1708. On *November* the 16th, 1707, a ſmall one appeared in *Ireland*. Since that of *March* the 6th, $17\frac{15}{16}$, they have been, and ſtill continue very common.

ſufficient to acquaint the Reader with all the Circumſtances wherewith they are attended. I ſhall therefore collect together ſuch *Phænomena*, as have been moſt generally obſerved, and reduce them to the ten following Propoſitions, adding in the Notes, by Way of *Specimen*, a full Account of that moſt remarkable *Aurora*, which was ſeen *March* the 6th $17\frac{15}{16}$, as it was laid before the *Royal Society* by Dr. *Halley*, at their Requeſt *.

The

* " On *Tueſday* the 6th of *March*, in the Year 1716 (the Af-
" ternoon having been very ſerene and calm, and ſomewhat
" warmer than ordinary) about the Time it began to grow dark
" (much about ſeven of the Clock) not only in *London*, but in
" all Parts of *England*, where the Beginning of this wonderful
" Sight was ſeen; out of what ſeemed a duſky Cloud, in the
" North-eaſt Parts of the Horizon, and ſcarce ten Degrees high,
" the Edges whereof were tinged with a reddiſh Yellow, like as if
" the Moon had been hid behind it, there aroſe very long lumi-
" nous Rays, or Streaks perpendicular to the Horizon, ſome of
" which ſeemed nearly to aſcend to the *Zenith*. Preſently after,
" that reddiſh Cloud was ſwiftly propagated along the northern
" Horizon into the North-weſt, and ſtill farther weſterly; and
" immediately ſent forth its Rays from all Parts, now here, now
" there, they obſerving no Rule or Order in their riſing. Many
" of thoſe Rays, ſeeming to concur near the *Zenith*, formed there
" a *Corona*, or Image, which drew the Attention of all Specta-
" tors. Some likened it to that Repreſentation of Glory, where-
" with our Painters in Churches ſurround the Holy Name of God.
" Others to thoſe radiating *Stars*, wherewith the Breaſts of
" *Knights* of the Order of the *Garter* are adorned. Many com-
" pared it to the *Concave* of the great *Cupola* of St. *Paul's*
" Church, diſtinguiſhed with Streaks alternately light and ob-
" ſcure, and having in the Middle a Space leſs bright than the
" reſt, reſembling the Lanthorn. Whilſt others, to expreſs as well
" the Motion as Figure thereof, would have it to be like the
" Flame in an Oven, reverberated and rolling againſt the arched
" Roof

The moſt general *Phænomena* of an *Aurora Borealis* are theſe that follow.

1. In the northern Parts of the *Horizon*, there is commonly the Appearance of a very black

" Roof thereof: Some thought it liker to that tremulous Light, " which is caſt againſt the Cieling by the Beams of the Sun, re- " flected from the Surface of the Water in a Baſon, that's a little " ſhaken. But all agree, that this *Spectrum* laſted only a few " Minutes, and exhibited itſelf variouſly tinged with Colours, Yel- " low, Red, and a dusky Green: Nor did it keep in the ſame " Place; for when firſt it began, it appeared a little to the " Northwards of the *Zenith*, but by Degrees declining towards " the South, the long *Striæ* of Light, which aroſe from all Parts " of the northern Semicircle of the *Horizon*, ſeemed to meet to- " gether, not much above the Head of *Caſtor*, or the northern " *Twin*, and there ſoon diſappeared.

" After the firſt *Impetus* of the aſcending Vapour was over, the " *Corona* appeared no more; but ſtill, without any Order, as to " Time or Place, or Size, luminous *Radii*, like the former, con- " tinued to ariſe perpendicularly, now oftener, and again ſel- " domer; now here, now there; now larger, now ſhorter. " Nor did they proceed as at firſt, out of a Cloud, but oftener " would emerge at once out of the pure Sky, which was more " than ordinary ſerene and ſtill. Nor were they all of the ſame " Form. Moſt of them ſeemed to end in a Point upwards, like " erect Cones; others like truncate Cones, or Cylinders, ſo much " reſembling the long Tails of Comets, that at firſt Sight, they " might well be taken for ſuch. Some of thoſe Rays would con- " tinue viſible for ſeveral Minutes; when others, and thoſe the " much greater Part, juſt ſhewed themſelves, and died away. " Some ſeemed to have little Motion, and to ſtand, as it were, " fixed among the Stars, whilſt others, with a very perceptible " Tranſlation, moved from Eaſt to Weſt under the Pole, contrary " to the Motion of the Heavens; by which Means they would " ſometimes ſeem to run together, and at other Times to fly one " another.

" After this Sight had continued about an Hour and a half, " thoſe Beams began to riſe much fewer in Number, and not near " ſo high; and by Degrees, that diffuſed Light, which had illuſ-

black Cloud; but it is evident that it is no real Cloud, becauſe the ſmalleſt Stars are viſible through it. This apparent Cloud is extended ſometimes farther towards the Weſt, than

" trated the northern Parts of the Hemiſphere, ſeemed to ſubſide,
" and ſettling on the Horizon, formed the Reſemblance of a very
" bright *Crepuſculum*. That this was the State of this *Phænomenon*,
" in the firſt Hours, is abundantly confirmed by the unanimous
" Conſent of ſeveral. For, by the Letters we have received from
" almoſt all the extreme Parts of the Kingdom, there is found very
" little Difference from what appeared at *London* and *Oxford*; un-
" leſs that in the North of *England*, and in *Scotland*, the Light
" ſeemed ſomewhat ſtronger and brighter.

" Hitherto I have related the Obſervations of others; as to
" myſelf, I had no Notice of this Matter, till about nine of the
" Clock: I immediately perceived toward the South and South-
" weſt Quarter, that though the Sky was clear, yet it was tinged
" with a ſtrange Sort of Light; ſo that the ſmaller Stars were
" ſcarce to be ſeen, and much as it is when the Moon of four
" Days old appears after Twilight. I perceived at the ſame Time
" a very thin Vapour to paſs before us, which aroſe from the pre-
" ciſe Eaſt Part of the Horizon, aſcending obliquely, ſo as to
" leave the *Zenith* about fifteen or twenty Degrees to the North-
" ward. But the Swiftneſs, wherewith it proceeded, was ſcarce to
" be believed, ſeeming not inferior to that of Lightning; and
" exhibiting, as it paſſed on, a Sort of momentaneous *Nubecula*,
" which diſcover'd itſelf by a very diluted and feint Whiteneſs;
" and was no ſooner formed, but before the Eye could well take
" it, it was gone, and left no Signs behind it. Nor was this a
" ſingle Appearance; but for ſeveral Minutes, about ſix or ſeven
" Times in a Minute, the ſame was again and again repeated;
" theſe Waves of Vapour regularly ſucceeding one another, and
" at Intervals very nearly equal; all of them in their Aſcent pro-
" ducing a like tranſient *Nubecula*.

" By this Particular we were firſt aſſured; that the Vapour we
" ſaw, became conſpicuous by its own proper Light, without the
" Help of the Sun's Beams; for theſe *Nubeculæ* did not diſcover
" themſelves in any other Part of their Paſſage, but only between
" the South-eaſt and South, where being oppoſite to the Sun,

" they

than to the East; sometimes farther towards the East, then to the West; and generally takes up a Quarter of the Horizon, more or less.

2. The

" they were deepest immersed in the Cone of the Earth's Shadow; " nor were they visible before or after. Whereas the contrary " must have happened, had they borrowed their Light from the " Sun.

" On the western Side of the northern Horizon, *viz.* between " West and North-west, not much past ten of the Clock, I ob- " served the Representation of a very bright Twilight, contiguous " to the Horizon, out of which arose very long Beams of Light, " not exactly erect towards the *Vertex*, but something declining " towards the South; which, ascending by a quick and undulating " Motion to a considerable Height, vanish'd in a little Time; " whilst others, though at uncertain Intervals, supplied their " Place. But at the same Time, through all the rest of the nor- " thern Horizon, *viz.* from the North-west to the true East, " there did not appear any Sign of Light to arise from, or join " to, the *Horizon*; but what appeared to be an exceeding black " and dismal Cloud, seemed to hang over all that Part of it. Yet " was it no Cloud, but only the serene Sky, more than ordinary " pure and limpid, so that the bright Stars shone clearly in it, " and particularly *Canuda Cygni*, then very low in the North; " the great Blackness manifestly proceeding from the Neighbour- " hood of the Light, which was collected above it. For the " Light had now put on a Form quite different from all that we " have been describing, and had fashioned itself into the Shape of " two *Laminæ*, or Streaks, lying in a Position parallel to the *Hori-* " *zon*, whose Edges were but ill-terminated. They extended them- " selves from the North by East to the North-east, and were each " about a Degree broad; the undermost about eight or nine Degrees " high, and the other about four or five Degrees over it; these " kept their Places for a long Time, and made the Sky so light, " that I believe a Man might easily have read an ordinary Print " by the Help thereof.

" Whilst I was viewing this surprizing Light, and expecting " what was farther to come, the northern End of the upper *La-* " *mina* by degrees bent downwards, and at length closed with " the End of the other that was under it, so as to shut up on the " North-Side an intermediate Space, which still continued open

" to

2. The upper Edge of this Cloud (which is ſometimes within leſs than ſix Degrees of the Horizon, and ſometimes forty or fifty above it)

" to the Eaſt. Not long after this, in the ſaid included Space, I " ſaw a great Number of ſmall Columns, or whitiſh Streaks, to " appear ſuddenly erect to the Horizon, and reaching from the " one *Lamina* to the other; which inſtantly diſappearing, were " too quick for the Eye, ſo that I could not judge, whether they " aroſe from the under, or fell from the upper; by their ſudden " Alterations, they made ſuch an Appearance, as might well " enough be taken to reſemble the Conflict of Men in Battle.

" And much about the ſame Time, there began on a ſudden to " appear, low under the Pole, and very near due North, three or " four lucid *Areas*, like Clouds, diſcovering themſelves in the " pure but very black Sky, by their yellowiſh Light. Theſe, as " they broke out at once, ſo after they had continued a few Mi- " nutes, diſappeared as quick, as if a Curtain had been drawn " over them: Nor were they of any determined Figure, but " both in Shape and Size might properly be compared to ſmall " Clouds illuminated by the full Moon, but brighter.

" Not long after this, from above the foreſaid two *Laminæ*, " there aroſe a very great *Pyramidal* Figure, like a Spear, ſharp " at the Top, whoſe Sides were inclined to each other, with an " Angle of about four or five Degrees, and which ſeemed to reach " up to the *Zenith*, or beyond it. This was carried with an " equable, and not very ſlow Motion, from the North-eaſt where " it aroſe, into the North-weſt, where it diſappeared, ſtill keep- " ing in a perpendicular Situation, or very near it; and paſſing " ſucceſſively over all the Stars of the *little Bear*, did not efface " the ſmaller ones in the Tail, which are of the fifth Magni- " tude; ſuch was the extream Rarity, and Perſpicuity of the " Matter whereof it conſiſted.

" This ſingle Beam was very remarkable for its Height above " all thoſe, that, for a great while before, had preceeded it, or " that followed it.

" It being now paſt eleven of the Clock, and nothing new of- " fering itſelf to our View, but repeated *Phaſes* of the ſame Spec- " tacle; I obſerved, that the two *Laminæ*, or Streaks, parallel " to the *Horizon*, had now wholly diſappeared; and the whole " Spectacle reduced itſelf to the Reſemblance of a very bright

" Cre-

it) is generally terminated with a very lucid Arch, from one to four or five Degrees broad, whoſe Center is below the Horizon. Sometimes

" *Crepuſculum* ſetting on the Northern *Horizon*, ſo as to be " brighteſt and higheſt under the Pole itſelf; from whence it " ſpread both Ways into the North-eaſt and North-weſt. Un- " der this, in the Middle thereof, there appeared a very black " Space, as it were the Segment of a leſſer Circle of the Sphere " cut off by the *Horizon*. It ſeemed to the Eye like a dark Cloud, " but was not ſo; for by the Teleſcope the ſmall Stars appeared " through it more clearly than uſual, conſidering how low they " were: And upon this as a *Baſis*, our *Lumen Auroriforme* reſt- " ed, which was no other than a Segment of a Ring, or *Zone* " of the Sphere, intercepted between two parallel leſſer Circles, " cut off likewiſe by the *Horizon*; or the Segment of a very " broad *Iris*, but of one uniform Colour, *viz.* a Flame-Colour " inclining to Yellow, the Center thereof being about forty De- " grees below the *Horizon*. And above this there were ſeen " ſome Rudiments of a much larger Segment, with an Interval " of dark Sky between, but this was ſo exceeding feint and " uncertain, that I could make no proper Eſtimate thereof.

" I attended this *Phænomenon* till near three in the Morning, and " the Riſing of the Moon: But for above two Hours together it " had no Manner of Change in its Appearance, nor Diminution, " nor Increaſe of Light; only ſometimes, for very ſhort Intervals, " as if new Fewel had been caſt on a Fire, the Light ſeemed to " undulate and ſparkle not unlike the riſing of a vaporous Smoak " out of a great Blaze when agitated. But one Thing I aſſured " myſelf of, that the *Iris*-like Figure did by no means owe its " Origin to the Sun's Beams: For that about three in the Morn- " ing, the Sun being in the Middle between the North and Eaſt, " our *Aurora* had not followed him, but ended in that very Point " where he then was: Whereas in the true North, which the " Sun had long paſſed, the Light remained unchanged, and in " its full Luſtre.

Appearances of this Kind have been taken Notice of both by *Pliny*, *Seneca* and *Ariſtotle*; the laſt of which calls the vibrating Light near the *Zenith*, Δαλοὶ; the more ſteady perpendicular Streams, Δοχόι; and the *Aurora* itſelf, from the apparent dark Cloud juſt below it, Χάσμα. That *Aurora* which was obſerved by

times there are two or more of theſe Arches, one above another. In ſome, the Cloud is not terminated by an Arch, but by a long bright Streak

by Monſieur *Gaſſendi* in *Provence*, on the 21ſt of *September*, in the Year 1621, was very remarkable, at that Time.

He tells us, That about the End of Twilight in the Evening, when the Sky was very clear, and there was no Moon, there appeared in the North a Sort of a riſing Morn, which aſcending by Degrees, became intermingled with certain Streaks, as it were, or Rays perpendicular to the Horizon: And that at the ſame Time there appeared ſome ſmall *paſſing* whitiſh Clouds between the South and the Place of the Sun's ſetting in Winter; and that in the Place where the Sun ſets in Summer, a bright Redneſs ſeemed to ariſe in the Form of a *Pyramid*, which moved towards the ſetting of the Sun at the *Equinox*; and which was diſtinguiſhed into three ſeveral *Pyramids*, which in a little Time were confounded one with another, and at laſt diſappeared. When this Redneſs ceaſed, the northern Whiteneſs was riſen forty Degrees and more, that is, about the Altitude of the Pole-Star, forming itſelf into an Arch, and taking up near ſixty Degrees of the *Horizon*. After this, certain *Chevrons*, or Columns of Rays, ſome whiter, and ſome a little darker, began more plainly to be diſtinguiſhed, of about two Degrees in Breadth, and perpendicularly poſited; ſo that all that Part appeared as it were fluted. The whole Circumference immediately appeared ſcalloped; and then ſome of thoſe Columns which were in the Middle, and that were the whiteſt, began as it were to leave their Places with great Impetuoſity, and in leſs than a Quarter of a Minute, raiſed themſelves almoſt to the Top, putting on the Form of *Pyramids*, which they would retain four or five Minutes. It was about nine of the Clock, when the Arch of Whiteneſs began to decreaſe or ſink; at which Time certain very white Streams of Smoke began to iſſue out from the Columns which were remaining under the *Pyramids*, and darting upwards with very great Rapidity through the *Pyramids*, like Javelins, vaniſhed immediately when they came to the Tops of them. This Spectacle laſted about an Hour; after which the Whiteneſs ſunk down to about ſix Degrees of the *Horizon*. *Vide Abregé de Gaſſendi*, Tom. V. P. 245.

This

Streak of Light, lying parallel to the *Horizon*. The Limb of this luminous Arch, or parallel Streak is not always even and regular, but ſinks lower in ſome Parts, than in others.

3, Out of this Arch proceed Streams of Light, generally perpendicular to the *Horizon*, but ſometimes a little inclined to it. Moſt of them ſeem to end in a Point, like *Pyramids* or *Cones*; and often very much reſemble the Tails of *Comets*. Sometimes there is no luminous Arch, nor Streak of Light; and then the Streams ſeem to iſſue out from behind the dark Cloud, being diſtinct from each other at their *Baſes*.

4. The upper Ends of the Streams inceſſantly appear and vaniſh again, as quick as if a Curtain were drawn backwards and forwards before them; which ſometimes cauſes ſuch a ſeeming trembling in the Air, that you would

This *Phænomenon* appeared not only to *Gaſſendi* in *Provence*, but was ſeen at Places very diſtant from thence, as at *Toloſe*, *Montaubon*, *Bourdeaux*, *Grenoble*, *Dijon*, *Paris*, and *Roan*, &c. and at moſt other Places in *France*, and the neighbouring Countries, that lie to the Northwards of *Provence*, unleſs where it was intercepted by Clouds; but no where in ſuch as lie at any great Diſtance to the Southwards of it.

Monſieur *Gaſſendi* is thought to have given the Name of *Aurora Borealis* to this *Phænomenon*; but this is obſerved by Monſieur *Mairan*, to be a Miſtake. See Mr. *Mairan*'s Phyſical and Hiſtorical Treatiſe of the *Aurora Borealis*, in the *Memoires de l'Academie Royale des Sciences*, *Année* 1731. or an Abſtract of it in Philoſoph. Tranſact. N°. 431.

imagine the upper Part of the Heavens to be, as it were, in Convulſions *.

5. They ſometimes ſeem to meet in the *Zenith*, or more commonly to the Southward of it, about ten Degrees, more or leſs (ſometimes they deviate a little to the South-eaſt of the *Meridian*, and ſometimes to the South-weſt); and there curling round, in ſome Meaſure, imitate Flame confined under an Arch; and being frequently tinged with various Orders of Colours, exhibit a moſt beautiful Appearance, reſembling a Canopy finely painted †, of about ten or twenty Degrees in Breadth.

In many *Aurora*'s, there are Streams aſcending from thoſe Parts of the Heavens, which lie ſeveral Degrees to the Southwards of the Canopy; and in ſome, they appear to ariſe, though very rarely, almoſt as large, and numerous from the ſouthern, as from the northern Parts of the Horizon.

6. The Height of the *Aurora Borealis* is very great; for that of *March* the ſixth $17\frac{5}{16}$ was viſible from the Weſt Side of *Ireland*, to the Confines of *Ruſſia* and *Poland* on the Eaſt, and perhaps farther; extending at leaſt over thirty Degrees of Longitude, and in La-

* See their Motions well deſcribed in the Account we have of an *Aurora* in the Philoſoph. Tranſact. N°. 395, Art. 2.

† See the various Colours of the Canopy, as well as thoſe of an *Aurora* itſelf, accurately deſcribed by Mr. *Greenwood*, in Philoſoph. Tranſact. N°. 418, Art. 1.

titud

titude from about the fiftieth Degree over almoſt all the North of *Europe*, and at all Places, exhibiting, nearly at the ſame Time, the ſame Appearances.

7. Theſe Appearances have always been very frequent (as far as the Accounts we have of them inform us) in Countries that lie in, or near the *frigid Zone*, but very rare in thoſe of our Latitude; they are now become very frequent with us, but always ſeem to proceed from the North; and are as yet unknown to the Inhabitants of the more ſouthern Parts of our *Hemiſphere*. Whether they are ſeen to thoſe, who inhabit in, or near the other *frigid Zone*, is to us unknown.

8 In ſome, there are Trains of Light running horizontally, ſometimes from the Middle to the Extremes, and ſometimes from one Extreme to the other. And from theſe Trains often ariſe Streams perpendicular to the *Horizon*, and accompanying them as they paſs along,

9. When all the Streaming is over, the *Aurora Borealis* commonly degenerate nto a bright Twilight in the North, and there gradually dies away.

10. It is probable, that theſe *Phænomena* often happen in cloudy Nights, though we are not ſenſible of them; for 'tis obſervable, that in ſuch Nights, there is frequently more Light

than what uſually proceeds from the Stars alone.

The moſt obvious Solution of the *Aurora Borealis*, or at leaſt what would appear ſo, to ſuch as have only attended to the Circumſtances of ſome particular ones, and which has accordingly been affixed by ſeveral * to their Accounts of the *Aurora*'s they have ſeen, is that it is a thin Nitro-ſulphureous Vapour, raiſed in our Atmoſphere conſiderably higher than the Clouds; that this Vapour by Fermentation takes Fire, and the Exploſion of one Portion of it kindling the next, the Flaſhes ſucceed one another, till the whole Quantity of Vapour within their Reach is ſet on Fire.

* Profeſſor *Cotes*, at the End of his Deſcription of a *Phænomenon* of this Kind, inſerted in the Philoſophical Tranſactions N°. 365, obſerves, that ſuppoſing a Fund of Vapours or Exhalations at a conſiderable Height above us to be diffuſed every Way into a large and ſpacious Plane, parallel to the *Horizon*, that Fund of mixed Matter by Fermentation will emit Streams; and that if the Wind be ſtill, they will aſcend perpendicularly upwards; otherwiſe they will be inclined towards that Point of the Horizon which is oppoſite to that from which the Wind blows; and that they will appear, by the Rules of Perſpective, in the firſt Caſe, to converge to the Spectator's *Zenith*, in the other, to ſome Point not far from it; and that if this Fund of Vapours be ſituated more to the North than the South, it will produce Streams of Light attended with ſuch Circumſtances, as then appeared: But he does not ſay, why the Vapours ſhould be ſituated rather to the North than the South, or proceed to account for all the *Phænomena* of the *Aurora Borealis* in general from thence.

Some

Some have thought, that Vapours rarefied exceedingly by ſubterraneous Fire, and tinged with ſulphureous Steams, might from thence be diſpoſed to ſhine in the Night, and riſing up to the Top of the Atmoſphere, or even beyond its Limits (as we find the Vapours of Gun-powder, when heated in *Vacuo*, will ſhine in the Dark, and aſcend to the Top of the Receiver, though exhauſted) might produce thoſe Undulations in the Air, which conſtitute this *Phænomenon*.

But theſe *Hypotheſes* have been rejected, as inſufficient: it having been thought impoſſible to account for all the Circumſtances of the *Aurora* by them *.

* In the Commentaries of the Academy of Sciences at *Petersburgh*, I find a late Solution of the *Aurora Borealis* from Exhalations fermenting and taking Fire in the Atmoſphere, which the Author *Chr. Maier* ſays, occaſion the Appearance of the lucid Arch in the North, and thinks that the Streams, which ſeem to iſſue from thence, are no other than the Light of that Arch reflected to us from the under Side of ſome thin Clouds, that lie above it. As to its appearing in the North rather than in the South, he ſuppoſes that may be owing to the Cold of thoſe Regions condenſing the Exhalations, and thereby rendering them more liable to ferment than they are in the ſouthern; but acknowledges ingenuouſly, that he has no Reaſon to ſuppoſe this, but its being neceſſary to his Solution. At the End he tells, That it was known in ancient Times as well as lately: But omits taking Notice, that it appears much oftener of late Years in our Climate than it uſed to do; and ſo avoids accounting for that Particular. *Vide Commentar. Academ. Scientiar. Imperial. Petropolitan.* Tom. I. p. 351.

Dr.

Dr. *Halley* therefore has Recourſe to the *magnetic Effluvia* of the Earth, which he ſuppoſes to perform the ſame Kind of Circulation with Regard to it, as the *Effluvia* of any particular *Terrella* * do with reſpect to that, *viz.* that they enter the Earth near the South Pole, and pervading its Pores, paſs out again at the ſame Diſtance from the northern: And thinks, they may ſometimes, by the Concourſe of ſeveral Cauſes very rarely coincident, and to us as yet unknown, be capable of producing a ſmall Degree of Light, either from the greater Denſity of the Matter, or perhaps from the greater Velocity of its Motion; after the ſame Manner, as we ſee the *Effluvia* of *Electric* Bodies emit Light in the Dark.

Monſieur de *Mairan* has given us a Phyſical and Hiſtorical Treatiſe of the *Aurora Borealis*, and endeavours to prove that it is owing to the *Zodiacal Light*, or the Atmoſphere of the Sun, ſpread on each Side of it along the *Zodiac* in the form of a *Pyramid*. This, he ſays, is ſometimes extended to ſuch a Length as to reach beyond the Orbit of our Earth, and then mixing itſelf with our Atmoſphere, and being of an *Heterogeneous* Nature, produces

* A round Magnet, ſo called from the Reſemblance it bears to the Earth.

the

the ſeveral Appearances, which are obſerved in the *Aurora Borealis* *.

I have juſt mentioned theſe two Solutions, becauſe they come from two very ingenious Philoſophers; though I doubt not but the Reader will agree with me, that they are much too fine ſpun to hold, and that they are no other than the ingenious *Reveries* of Perſons determined to frame an Hypotheſis at any Rate. I queſtion not, but we may find Materials for the *Aurora Borealis*, without going ſo far for them, as theſe Gentlemen have done; and in particular that we have no Occaſion to have Recourſe either to the *magnetic Effluvia* of the Earth, or the *Zodiacal* Light, the Nature of both which we are wholly unacquainted with. The Materials employed in the firſt Solution (I mean ſuch *Effluvia* as are continually exhaled from the Surface and Bowels of the Earth) if rightly conſidered, will afford a very eaſy and natural one, as I ſhall endeavour to ſhew in the following Manner.

Firſt, we are aſſured by Experiment, that there are ſome Steams (as inflammable ſulphureous ones) which are capable of ſo great a Degree of Expanſion, that they will render themſelves lighter than the Air they float in, though it

* See his Account at large, referred to at the End of Note, Page 155.

be

Dr. *Halley* therefore has Recourſe to the *magnetic Effluvia* of the Earth, which he ſuppoſes to perform the ſame Kind of Circulation with Regard to it, as the *Effluvia* of any particular *Terrella* * do with reſpect to that, *viz.* that they enter the Earth near the South Pole, and pervading its Pores, paſs out again at the ſame Diſtance from the northern: And thinks, they may ſometimes, by the Concourſe of ſeveral Cauſes very rarely coincident, and to us as yet unknown, be capable of producing a ſmall Degree of Light, either from the greater Denſity of the Matter, or perhaps from the greater Velocity of its Motion; after the ſame Manner, as we ſee the *Effluvia* of *Electric* Bodies emit Light in the Dark.

Monſieur de *Mairan* has given us a Phyſical and Hiſtorical Treatiſe of the *Aurora Borealis*, and endeavours to prove that it is owing to the *Zodiacal Light*, or the Atmoſphere of the Sun, ſpread on each Side of it along the *Zodiac* in the form of a *Pyramid*. This, he ſays, is ſometimes extended to ſuch a Length as to reach beyond the Orbit of our Earth, and then mixing itſelf with our Atmoſphere, and being of an *Heterogeneous* Nature, produces

* A round Magnet, ſo called from the Reſemblance it bears to the Earth.

the

the ſeveral Appearances, which are obſerved in the *Aurora Borealis* *.

I have juſt mentioned theſe two Solutions, becauſe they come from two very ingenious Philoſophers; though I doubt not but the Reader will agree with me, that they are much too fine ſpun to hold, and that they are no other than the ingenious *Reveries* of Perſons determined to frame an Hypotheſis at any Rate. I queſtion not, but we may find Materials for the *Aurora Borealis*, without going ſo far for them, as theſe Gentlemen have done; and in particular that we have no Occaſion to have Recourſe either to the *magnetic Effluvia* of the Earth, or the *Zodiacal* Light, the Nature of both which we are wholly unacquainted with. The Materials employed in the firſt Solution (I mean ſuch *Effluvia* as are continually exhaled from the Surface and Bowels of the Earth) if rightly conſidered, will afford a very eaſy and natural one, as I ſhall endeavour to ſhew in the following Manner.

Firſt, we are aſſured by Experiment, that there are ſome Steams (as inflammable ſulphureous ones) which are capable of ſo great a Degree of Expanſion, that they will render themſelves lighter than the Air they float in, though it

* See his Account at large, referred to at the End of Note, Page 155.

be

be as rare, as it can be made by Art; for they will riſe to the Top of the Receiver, when exhauſted *, that is when as much Air, as is poſſible, is drawn out †: Such Steams therefore or Exhalations, riſing out of the Earth from Mines, Vulcano's, *&c.* muſt neceſſarily be buoyed up towards the Top of the Atmoſphere, at leaſt, till they come to a Region, where the Air is as rare and expanded, as it can be made by the *Air Pump*, here below. This Height according to Dr. *Halley*'s Computation §, (which he found upon the Degree of the Air's Elaſticity) is about forty or fifty Miles: but probably it is much greater; for the Air, which is higher than Vapours and other *Heterogeneous* Matter that is not elaſtic, riſe to, being much purer than any we can make Experiments upon, may be indued with a much greater Degree of Elaſticity, and ſo the Atmoſphere may be conſiderably higher, than what he upon that Principle, computes it to be.

Secondly, Theſe *Effluvia* being raiſed to the Top of the Atmoſphere, or near it, and floating there, will neceſſarily be carried towards the poplar Parts thereof, for the following Reaſons. 1. Becauſe the ſuperior Current

* See Philoſoph. Tranſact. N°. 347 and 360.

† It is impoſſible to extract all the Air out of a Veſſel, becauſe it is by the Spring of the Air remaining in the Veſſel, that the Valves of the Pump are opened at each Stroke.

§ Philoſoph. Tranſact. N°. 181.

of

of the Air, to a great Diſtance from the *Equator*, is that Way *. 2. We know from Experiment, that whatever ſwims upon a Fluid which revolves about an *Axis*, is thereby carried towards that *Axis*. This is exactly the Caſe of theſe *Effluvia*, for they ſwim near the Top of the Atmoſphere which continually revolves about the *Axis* of the Earth; they muſt therefore neceſſarily be carried towards the polar Parts thereof.

Thirdly, Theſe *Effluvia* being collected together at, or near the Poles, and of an inflammable Nature, may eaſily be ſuppoſed to ferment, when they meet with other *heterogeneous* ones proper to produce ſuch an Effect, and emit Streams of Fire; which Streams will naturally riſe up into ſuch Parts of the Atmoſphere as are ſtill lighter than that wherein the *Effluvia* reſt, that is, directly upwards from the Center of the Earth. But, according to the Rules of *Perſpective*, thoſe Streams, though they really diverge, as *Radii* from a Center, will appear to a Spectator on the Surface of the Earth to converge towards a Point: Which Point will ſeem to be directly over his Head, if the Streams aſcend in right Lines from the Center of the Earth: but if they deviate all one Way from that Direction, the Point will be on

* As explained in Diſſertation V.

that Side the *Zenith* towards which they incline *.

To illuſtrate this; ſuppoſe ſeveral Strings hung down from the Ceiling of a Room, and a Candle placed upon a Table below them, the Shadows of them all will converge towards the Point, that is over the Candle. And, if they are made to incline, ſuppoſe all one Way, the Point of Convergency will remove from over the Candle, towards that Side of the Room to which the upper Ends of the Strings incline: Now if a Perſon had viewed them from the Place where the Candle was, and referred their Places to the Ceiling, they would have ſeemed to him to have converged towards the Point, where their Shadows did.

And if the Streams ſpread themſelves as they ariſe, but not too much, they will nevertheleſs appear tapering towards the upper Ends, like *Cones* or *Pyramids*; juſt as the Sides of a long Walk ſeem to a Perſon that views them

* This may be made to appear in the following Manner; Let ADB (*Fig.* 38.) repreſent the *Concave* of the Heavens, AB the *Horizon*, C the Place of the Spectator, TV a luminous Subſtance ſending forth the parallel Streams EG, LM, NO, *&c.* Theſe Streams will all ſeem to converge towards the Point D, if that Point be taken ſuch, that the Line DC drawn from thence to the Spectator's Eye, be parallel to the Streams. For Inſtance, the Stream EG will ſeem to riſe from *e* to *g*, LM from *l* to *m*, and FH from *f* to *h*, and ſo of the reſt. And NO will appear wholly in D the Place to which the reſt ſeem to converge. And if the Streams are as large, or ſomewhat larger at the upper Ends, than at the lower, they will ſtill appear leſs there, thoſe Ends being fartheſt from the Spectator's Eye.

from

from one End of it, or from a diſtant Place, to approach each other at that which is fartheſt from him.

This being premiſed, we may now account for the ſeveral *Phænomena* of the *Aurora Borealis* before laid down. As,

1. The Blackneſs of the Sky, which generally appears in the northern Parts of the *Horizon*, like a dark Cloud, is occaſioned by the Brightneſs of the luminous Matter of the *Aurora* juſt above it. That the Sky is clear here, is evident (as was obſerved before) becauſe the ſmalleſt Stars are ſeen through it.

2. The lucid Arch immediately above, is the luminous Matter of the *Aurora* itſelf, which ſometimes exhibits the Appearance of a Curve, ſometimes of a ſtrait Line, according to its Form and Situation in the Atmoſphere, though generally that of a Curve: For, by the Rules of *Perſpective*, when a ſtrait Line is diſtended horizontally, and above the Spectator's Eye, it ought to appear bent into a Curve, whoſe Center is below the *Horizon* *. Sometimes it appears on one Side the North Point, more

* Thus, when a Perſon ſtands fronting a Row of Houſes, and looks over the Tops of them, if they are all of an equal Height, that Houſe which is neareſt him, will ſeem to cut the Heavens in a Point that will be higher than where it is cut by any of the reſt; and the Points where the Heavens will ſeem to be cut by the Tops of thoſe, which are on the Right and Left Hand of the Spectator, will deſcend lower and lower, as the Houſes are farther off; ſo that the Points, taken all together, will repreſent a Curve.

than on the other; ſometimes regular, ſometimes irregular, as the various Circumſtances of the Air's Motion at the Top of the Atmoſphere, and of the Situation of the flaming Matter may be.

3. The Streams of Light, iſſuing out of the lucid Arch, are Streams of Fire emitted upwards from the Matter of the *Aurora*, and ſeem, for the Reaſons already laid down, to converge towards the *Zenith* of the Spectator. Why they incline a little ſometimes from the Perpendicular, will be explained in the fifth Remark, where we account for the Situation of the Canopy. When no luminous Arch appears, it is probable, that it is intercepted by the *Horizon*, or by the Vapours which float in great Quantities therein.

4. The trembling obſerved in the upper Part of the Heavens, is owing to the Quickneſs wherewith the Flaſhes ſucceed one another, and alſo to the irregular Motions and Agitations of the ſuperior Parts of the Atmoſphere.

5. So long as the luminous Matter of the *Aurora* is all of it towards the North of us, the Streams cannot ſeem to meet in a Point at the Top, as will appear to any one that conſiders the Figure referred to in the Note (p. 164), but after it has advanced forwards, or become kindled over our Heads, then they appear to meet, and form the Canopy already deſcribed; and when it has paſſed further ſtill, they ſeem to

to ariſe from all Parts; though they are much fainter on the ſouthern than on the northern Side, ſo long as the main Body of the *Aurora* remains on the northern Side of the Canopy, which it rarely, if ever, paſſes. The Reaſon why the Center of the Canopy is generally a few Degrees to the South of the Spectator's *Zenith* *, is becauſe the luminous Streams, which iſſue forth from the extreme Parts of the Subſtance of the *Aurora*, will naturally diverge a little from the middle ones; and, as thoſe which appear to us, proceed chiefly from the ſouthern Side (that being neareſt to us) the Point of Convergency will neceſſarily be placed to the South of our *Zenith*, according to what was ſaid above about the Inclination of the Strings hanging from the Cieling of a Room. If the Center of the Canopy is ſometimes to the Eaſtward, and ſometimes to the Weſtward of the Meridian, that depends upon the Motion of that Part of the Air, which is above the Subſtance of the *Aurora*, and through which the Streams paſs, as they riſe. This alſo it is that makes the Streams ſeem to ariſe ſometimes a little obliquely.

* According to this Theory, the Center of the Canopy will always be near the Spectator's Zenith, where-ever he is; which I believe is the Caſe, for I have met with no Account where it is otherwiſe; and ſo every Spectator ſees a different Canopy, juſt as when ſeveral Perſons are viewing a Rainbow, no two Perſons ſee the ſame Rainbow at the ſame Time.

6. The

6. The great Height of the *Aurora* is owing to the exceeding Lightneſs of the *Effluvia*, which compoſe the Subſtance of it (as explained above) and the darting of the Streams upwards, into Regions perhaps quite above the Atmoſphere, occaſions it to exhibit at very diſtant Places the ſame Appearances at the ſame Time.

7. That the *Aurora* appears near the *Pole*, and never at or near the *Equator*, is becauſe of the Tendency the Matter of it has towards the Poles, as explained above. And that it appears in Places more diſtant from the *Pole*, than it formerly did, is becauſe the *Effluvia*, which are now raiſed from the Earth, are prevented from approaching ſo near the polar Parts of the Atmoſphere, as they uſed to do; thoſe Parts being already ſtocked with others, which were formerly raiſed, and are now grown *effete* by frequent Fermentations and Exploſions.

8. The *horizontal* Trains of Light are the Subſtance of the *Aurora* juſt taking Fire, which runs from one Part to another, as in a Train of Gunpowder kindled in any one Part; and ſends up Streams perpendicularly from Places, where it meets with a greater Quantity of Matter than ordinary.

9. When the Matter of the *Aurora* is ſo far ſpent, as to emit no more Streams, it appears only as a bright ſteady Light in the North, which

which gradually dies away, for Want of freſh Fewel to ſupport it.

10. As the Vapours, of which Clouds are formed, never riſe ſo high, as where the Matter of the *Aurora Borealis* floats; it is not at all inconſiſtent with the foregoing Theory, if it is ſometimes intercepted from our Sight, by the Interpoſition of Clouds below.

See farther on this Subject, *Ariſtotel.* Meteor. Lib. I. Cap. 4, 5. *Plinii* Hiſtor. Natural. Cap. 26, 27. *Senec.* Quæſt. Natural. Lib. I. *Lycoſt.* Prodigiorum ac Oſtentorum Chronicon, paſſim. *Julius Obſequens* de Prodigiis, Cap. 13, 43, 88. *Gaſſendi* Animadverſ. in *Diog. Laert.* Lib. X. p. 1157. *Cornelius Gemma* de divinis Naturæ Characteriſmis. *Nicephori* Hiſtor. Eccleſiaſt. Lib. XII. Cap. 37. *Iſid. Hiſpal.* Hiſtor. Goth. Tom. I. p. 65. Bibliothec. Orientalis Clementino-Vaticana, Tom. I. p. 407. *Gregor. Tur.* paſſim. Mem. de Lit. de l'Acad. des Inſcriptions & belles Lettres, Tom. IV. p. 431. Miſcellan. *Berolin.* Tom. I. p. 137. Theatr. Comet. *Staniſ. Lubienietz.*, p. 264, 348. Mem. pour ſervir â l'Hiſtor. de *France*, Tom. I. p. 168. Mem. de l'Acad. Royal. de Sciences, for almoſt each Year ſince 1716. Philoſoph. Tranſ. N°. 305, 310, 320, 347, 348, 349, 351, 352, 363, 365, 368, 376, 385, 395, 398, 399, 402, 410, 418, 431; and the Authors referred to by Mr. *Johnſon*, in his Quæſt. Philoſoph. Cap. IV. §. 3,

DISSERTATION VIII.

Of Fermentation.

HAving had Occaſion to mention ſome of the Effects of Fermentation, it may not be amiſs, before I put an End to theſe Diſſertations, to add a ſhort Account of the Nature of it, and to ſhew how thoſe Effects are produced by it.

Fermentation is a mutual Commotion of the conſtituent Particles of Bodies, one among another; and ariſes from an Inequality in their Attractions of Coheſion. Authors diſtinguiſh it into two Kinds; the one is that which happens when a Solid is diſſolved by a Fluid; the other is, when two Fluids, being mixed together, ferment with each other.

Thoſe Authors, who have treated of the firſt of theſe, tell us, That to cauſe a Fermentation between a Solid and a Fluid, ſeveral Circumſtances are neceſſary. Particularly Dr. *Friend**, and *Keil*† are of Opinion,

1. That the Particles of the Solid muſt attract thoſe of the Fluid with a greater Force, than the Particles of the Fluid attract one another.

* See his Chemical Lectures.

† See his Letter to Dr. *Cockburn*, *De Legibus Attractionis*.

2. That

2. That the Pores of the Solid muſt not be too ſmall to admit the Particles of the Fluid into them.

3. That the Body be of ſo looſe a Contexture, that the Force of Impact, with which the Particles of the Fluid ruſh into its Pores, may be ſufficient to diſunite its Parts.

4. That the Elaſticity of the Particles tends very much to promote, and augment the Fermentation.

Pr. *Boerhaave* makes alſo four Conditions requiſite *.

1. That there be a due Proportion between the Size of the Particles of the Fluid, and the Pores of the Body to be diſſolved.

2. That the Figure of the Particles of the Fluid have a determinate Relation to that of the Pores of the Solid.

3. That the Particles of the Fluid be ſufficiently ſolid, that their Moment, or Force of Action may not be too weak.

4. The laſt Qualification, he mentions, is a fit Diſpoſition of the Particles of the Fluid, when received into the Pores of the Solid, to make ſome ſtay there, and not immediately to paſs through; but to act every Way upon the Solid, as they move towards the external Surface thereof.

* Pr. *Boerhaave*'s Chemiſtry, by *Shaw*, p. 344.

But we have no Occaſion to have Recourſe to ſo many Suppoſitions; if the Particles of the Solid attract thoſe of the Fluid with a greater Degree of Force than either thoſe of the Fluid, or thoſe of the Solid attract one another *, it is ſufficient; and there will follow a Diſſolution of the Body, as may clearly be demonſtrated from the Laws of *Mechanics*, whatever the other Circumſtances relating to the Figure or Magnitude of Pores, *&c.* may be †.

When

* This may be thought an impoſſible Suppoſition, for the Force of Attraction of Coheſion being as the Surfaces of the attracting Particles, whatever Size or Form the Particles of the Solid and Fluid are of, there cannot be a greater Quantity of Surface between every two Particles, one of which is a Particle of the Solid, and the other a Particle of the Fluid, than there is between every two Particles, which are either both of the Solid, or both of the Fluid; and therefore the Particles of the Solid cannot attract thoſe of the Fluid with greater Force than either thoſe of the Solid or thoſe of the Fluid attract one another. But it is to be conſidered, that we are not ſo well acquainted with the Nature of the Attraction of Coheſion, as to determine *exactly* in what Manner, and by what Laws it acts. The Experiments made Uſe of for this Purpoſe, only ſhew that ſo long as we try them with the ſame Kind of Bodies, the Attraction is larger where the Contact is ſo. See Part I. Chap. III. But we have no Method of determining, whether the Difference of Attraction, which *various* Bodies exert upon one another, ariſes ſolely from a Difference in their Surfaces, or not.

† *Dem.* Thus, let *f*, *f*, *f*, *&c.* (*Fig.* 39.) repreſent a Series of the Particles of a Fluid, and *s*, *s*, *s*, *&c.* a Series of thoſe of a ſolid Body, contiguous to one another: and let the pricked Lines *ff*, *ff*, *&c.* repreſent the Forces of Attraction between the Fluid Particles one among another, and *ss*, *ss*, *&c*, thoſe of the ſolid ones among themſelves; and let the black Lines *fs*, *sf*, *&c.* expreſs thoſe which are between the fluid and ſolid Particles. Now, the latter Forces being by the Suppoſition ſtronger than the former, the fluid Particles will recede from

When a Solid is put into a Fluid, if their Particles have the above-mentioned Relation to each other, thoſe of the Solid, being attracted with greater Force towards the Fluid, than they are the contrary Way, they will fall off from the Fluid, and enter in between the Particles of the Fluid; and for the like Reaſon, thoſe of the Fluid will open to themſelves a Way in between thoſe of the Solid, and will ſeparate them from each other. Neither will their Reſpective Motions ceaſe, unleſs their

from each other, and ſuffer thoſe of the Solid to enter in between them; and for the ſame Reaſon the ſolid Particles will give Way to thoſe of the Fluid. By which means, the Diſtances repreſented by the pricked Lines becoming greater, the Attractions, which they expreſs, will be diminiſhed; ſo that the fluid Particles will enter quite in between the ſolid ones, and the ſolid ones between the fluid one; and both of them together will conſtitute ſuch a Series, as is repreſented in *Figure* 40, in the middle Row *s*, *f*, *s*, *f*, *&c.* where the ſolid and fluid Particles lie mixed interchangeably one with another in a right Line. Now let it be ſuppoſed, that this Series is contiguous to one which conſiſts wholly of Fluid above it, as is expreſſed in the Figure, and to another below, conſiſting of ſolid Particles only. Every ſolid Particle in this Series will be attracted upwards with greater Force, than it is downwards; and every fluid one with greater Force downwards than it is upwards, as appears by bare Inſpection of the Figure, where the black Lines, as in the former, expreſs the ſtronger Attractions, and the pricked ones the weaker. And, if we ſuppoſe the Number of Particles in the Solid and in the Fluid to be nearly equal, thoſe of the Fluid will not ſtop, till they have quite paſſed through the Solid; for they will always find a Series wholly conſiſting of ſolid Particles before them, whilſt that which they leave behind, will be a Mixture of both. In like manner, the ſolid ones will paſs quite through the fluid ones; for they will always meet with more fluid ones before them, than they leave behind within the Sphere of their own Attraction.

Quantities be very unequal, till they are diffuſed uniformly one among another, as we may very eaſily conceive; for till then, there will always be ſome Particles attracted with a greater Degree of Force one Way than they are another.

And if more of the Solid be added to this Fluid, the Particles of the Fluid will alſo enter into that Solid, till each is ſurrounded on all Sides with ſolid Particles, as far as its attractive Force reaches. After which the Fluid is ſaid to be *ſaturated*, and will diſſolve no more.

Again, if more of the Fluid be poured upon that Solid, the ſolid Particles will diffuſe themſelves farther into the Fluid, till each of them is encompaſſed with Particles of the Fluid, as far as its attractive Force extends; and then they will ſpread themſelves no farther.

But in either Caſe, if another Solid, or Fluid, the attractive Force of whoſe Particles differ from thoſe of the former, be added, a freſh Fermentation will begin, provided the attractive Forces between the Particles of the former Mixture, and of thoſe which are now added, have ſuch Relation to each other, as is neceſſary to produce it.

Upon this Principle it ſhould ſeem, that a Fluid ſhould always be capable of diſſolving more than an equal Quantity of a Solid; and that a Solid ſhould be capable of entring in and

and diffuſing itſelf through more than an equal Quantity of Fluid. The Reaſon why it is frequently not ſo, is, becauſe it commonly happens, that the Fluid and the Solid are not of equal ſpecific Gravities. When the Solid is heavieſt, ſo many of its Particles will not aſcend and enter into the Fluid, as would otherwiſe have done; and on the contrary, when the Fluid is heavieſt, the Weight of its Particles will be an Impediment to their riſing into, and diſſolving the Solid.

We have no Occaſion to diſtinguiſh Fermentation into two Kinds, with regard to its Cauſes; for, according to the foregoing Theory, whenever two Fluids, or a Solid and a Fluid, are put together, if the Particles of the one attract thoſe of the other, with greater Force than either thoſe of the one, or thoſe of the other attract themſelves, a Fermentation will *equally* enſue, the Cauſe being the ſame in both Caſes.

When two Fluids, or a Solid and a Fluid, ferment with each other, if the Agitation and *inteſtine* Motion of their Particles be very great, or continues a long Time, and if the Subſtance of them be of the inflammable Kind, they will, by continually rubbing one againſt another, be ſufficiently heated to take Fire, and burſt out into Flame; as was ſaid of the ſeveral Compoſitions mentioned in the foregoing Diſſertation.

See the Authors, who have explained and defended the old Solution, referred to by Mr. *Johnſon* in his Quæſtiones Philoſoph. Cap. III. Quæſt. 5, 6, 7.

The End of the Second Part.

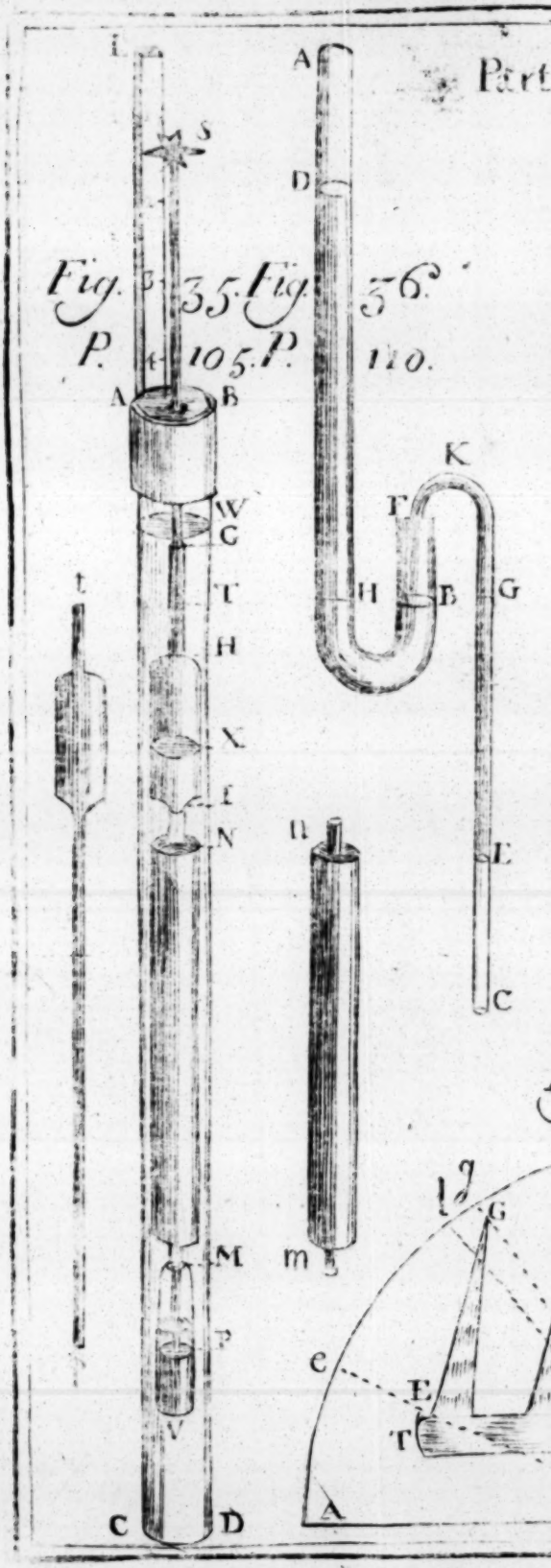
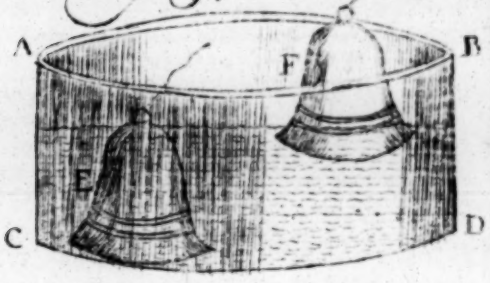


Fig. 35. P. 105.

Fig. 36. P. 110.

Fig. 37. P. 135.



36.
110.

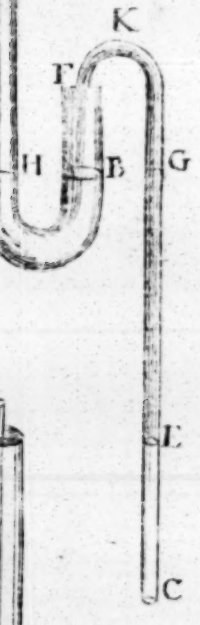


Fig. 39. P. 172.

Fig. 40. P. 173.

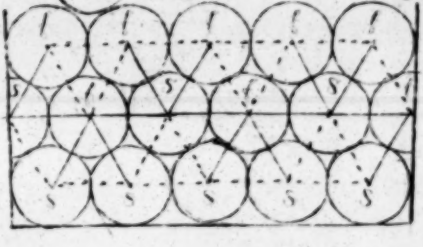


Fig. 38. P. 164.